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SSPC The Society For Protective Coatings
The Voice of SSPC: The Society for Protective Coatings

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FEATURES

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DEPARTMENTS

FROM THE OFFICES OF SSPC The Society For Protective Coatings

ALSO THIS ISSUE

STAFF

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Editorial

Quality Training Without Compromise

Raise your hand if you've taken SSPC training in the past 10 years.

Here are some interesting facts: SSPC currently has 47 coatings-related training and certification programs covering surface preparation, coating application, coating inspection, project management, quality control and other key topics. Over the past 10 years, more than 40,000 students have taken advantage of SSPC training and certification — in the past five years, over 26,000. In 2014 alone we trained over 6,000 people around the world. SSPC training has taken place in 28 countries since 2005. We have 16 training licensees covering 35 different countries. Study after study tells us that a well-educated workforce leads to happier, safer and better-paid workers, which then leads to higher quality projects and longer life cycles.

Asset owners are under great pressure to extend the service life of their structures and reduce overall costs, so they've turned to organizations like SSPC to provide high quality programs that develop the workforce into a finely tuned engine.

What's so special about SSPC training, you ask? Simply put, SSPC is the Harvard of coatings training. Our programs are *difficult*. When you enroll in an SSPC program, you've got to totally commit yourself to a week of demanding work. You will spend hours in class and hours more studying. We do not compromise on content or quality. We pay attention to details that other organizations might gloss over. We help students become skilled professionals by delivering core content that raises the bar on professional knowledge. Our courses contain relevant, focused information that challenges even industry veterans and doesn't bog students down with distracting filler designed to add days to the course and dollars to the cost. You train, you learn, you go. And if you pass, you know it was well earned.

SSPC programs are efficient and effective because we know that your time is valuable. The prices are reasonable and the credential is recognized worldwide. Our programs also do something unique in the coatings industry: they require students to have actual relevant industry experience to achieve certification. A mandatory requirement for on-the-job experience before certification is attained is a key building block of all SSPC certification programs. Certification without experience doesn't make sense. It can put people in dangerous situations and it can be misleading to customers who have higher performance expectations.

That's why experience is built into every certification we offer, from CAS to PCI. When you hire someone certified by SSPC, you are getting the cream of the crop because we've built our programs that way from the start.

SSPC is more than comfortable leading the way on this issue, and we welcome others who are adopting this approach because we think it's *that* important to the industry. We will continue to develop programs that the industry is asking for and continue to demand the best from the people who take them. You should, too. And if we're ever not meeting your expectations, let us know. We're tough enough to admit when we've made a mistake and honest enough to fix it.

In a few weeks, SSPC is heading to San Antonio, Texas for our annual conference. Our biggest training event of the year coincides with the conference — more courses in one place at one time than any other opportunity. If you're looking to raise the bar for yourself or your workforce, join us in San Antonio. For a complete list of SSPC training courses being offered at SSPC 2016, please visit www.sspc2016.com.

I hope you see you there!

Michael Kline
Director of Technology & Communications
SSPC

Final Free Webinars of 2015 Offered in December


Bill Corbett


Earl Bowry

Participants will be eligible to receive SSPC credits by taking part in the last two free online installments of the 2015 SSPC/*JPCL* Webinar Education Series in December.

"Shop/Field Testing of Abrasives for Compliance to SSPC Abrasive Standards," will be presented by Bill Corbett of KTA-Tator, Inc., on Tuesday, Dec. 8, from 11:00 a.m. to noon EST. SSPC maintains four Abrasive (AB) Standards, including AB 1 for mineral and slag abrasives, AB 2 for the cleanliness of recycled ferrous metallic abrasives, AB 3 for ferrous metallic abrasives and AB 4 for recyclable encapsulated abrasive media. This webinar on shop/field testing of abrasives for conformance to SSPC Abrasive Standards will describe the conformance tests invoked for each of these standards along with sampling frequencies. Additional "pre-production" field tests that may benefit the contractor (e.g., surface profile yield) will also be described. This webinar is sponsored by Chlor*Rid.

Bill Corbett is vice president and the professional services business unit manager for KTA-Tator, Inc. He holds an associate degree in business administration from Robert Morris University and has been employed by KTA for over 36 years. He has conducted coatings training courses and instrument use workshops for a variety of industries in both the private and public sector for 26 years. He is an SSPC-certified Protective Coatings Specialist, Level 3 Protective Coatings Inspector, and Level 2 Bridge Coatings Inspector; and a NACE-certified Level 3 Coating Inspector. Corbett is a lead instructor for SSPC's Bridge Coatings Inspector, Protective Coatings Inspector and Applicator Train-the-Trainer courses, and he chairs the SSPC committees on education and coating thickness measurement. He was a co-recipient of the SSPC 1992 Outstanding Publication Award and the 2001 *JPCL* Editors' Award, and he received SSPC's Coatings Education Award in 2006 and the John D. Keane Award of Merit in 2011.

"Standards, Training and Certification in the Marine Industry," will be presented by Earl Bowry of EVB Solutions, LLC on Wednesday, Dec. 16, from 11:00 a.m. to noon EST. This webinar will provide information on current training and certification programs related to industry standards and practical aspects of selecting, specifying and using coatings safely, effectively and economically to protect structures in harsh marine environments.

Bowry has more than 40 years of experience in industrial and marine coatings. He has held positions as an independent coating contractor, an independent coating inspector and as a sales and technical representative for Carboline Company and Jotun Paints Inc. He has also served as a subject matter expert for coatings for Newport News Shipbuilding. Bowry is an instructor for both NACE and SSPC Coatings Inspection, Coating Technology, Surface Preparation and Applicator courses; he also serves as a proctor for the SSPC Coatings Application Specialist (CAS) program. Bowry is an SSPC- and NACE-certified Protective Coatings Specialist and an SSPC-certified Level 2 Protective Coatings Inspector and a NACE-certified Level 3 Coating Inspector.

Registration, CEU Credits

These programs are part of the SSPC/*JPCL* Webinar Education Series, which provides continuing education for SSPC re-certifications and technology updates on important topics. SSPC is an accredited training provider for the Florida Board of Professional Engineers (FBPE), and Professional Engineers in Florida may submit SSPC Webinar Continuing Education Units to the board. To do so, applicants must download the FBPE CEU form and pass the webinar exam, which costs $25. Register for these online presentations at paintsquare.com/webinars.

OSHA Reveals Most Frequent Violations

Fall protection once again tops the list of safety violations in 2015, OSHA revealed at a National Safety Council conference last week. Hazard communication, scaffolding and respiratory protection take spots 2 through 4.

The preliminary top 10 list reflects the most frequently cited workplace safety violations data as of Sept. 8, the NSC said on Sept. 29. The preliminary Top 10 violations for 2015 are displayed below.

"In injury prevention, we go where the data tell us to go," said Deborah A.P. Hersman, NSC president and CEO. "The OSHA Top 10 list is a roadmap that identifies the hazards you want to avoid on the journey to safety excellence."

The rankings show very little change from the 2014 data, according to *OSHA Today*. Overall, the total number of violations to date, 34,436, is just a 4-percent increase over the 2014 totals. Fall protection citations, which were reported to have decreased by a third in 2014, jumped up 10 percent in 2015. Only the electrical categories (Electrical – Wiring Methods and Electrical – General Requirements) showed a decrease in violations for 2015.

This is the fifth consecutive year that fall protection citations have topped the list, *Safety + Health*, the official magazine of the NSC, reported. During his presentation of the Top 10 list to safety professionals at the 2015 NSC Congress & Expo, Patrick Kapust, deputy director of OSHA's Directorate of Enforcement Programs, commented on the first-place position of fall protection among violations. "Fall protection systems are out there," he said. "They're moderately priced. There's no reason your employees shouldn't be in them."

Final data for the year will be printed in *Safety + Health* in December, according to the NSC.

Rank	Standard Category	Standard	Citations
1	Fall Protection	1926.501	6,721
2	Hazard Communication	1910.1200	5,192
3	Scaffolding	1926.451	4,295
4	Respiratory Protection	1910.134	3,305
5	Lockout/Tagout	1910.147	3,002
6	Powered Industrial Trucks	1910.178	2,760
7	Ladders	1926.1053	2,489
8	Electrical – Wiring Methods	1910.305	2,404
9	Machine Guarding	1910.212	2,295
10	Electrical – General Requirements	1910.303	1,973

New CEO at Sherwin-Williams Announced

The Sherwin-Williams Company has turned to one of its long-standing managers to lead the company starting next year.

John G. Morikis

John G. Morikis, who has been with the Cleveland-based coatings company for more than 30 years, will take on the role of chief executive officer (CEO) beginning Jan. 1, 2016. He was also immediately elected to the company's Board of Directors.

Christopher M. Connor

Morikis, who has served as Sherwin-Williams' chief operating officer (COO) for the past nine years, will become the company's ninth CEO in its 150-year history, the company's Board of Directors said Oct. 19 in a statement about the leadership change. He will replace current CEO Christopher M. Connor, who will become the company's executive chairman.

Morikis, 52, joined Sherwin-Williams in 1984 as a management trainee in the company's Paint Stores Group. As COO, he helped to grow the company from $7.8 billion to $11 billion in revenues and earnings, the company said. In the Paint Stores Group alone — of which Morikis served as president at one point during his 31-year tenure — the company credits the incoming CEO with increasing the number of stores from 2,400 to 3,100 and generating an additional $2 billion in sales, according to the Sherwin-Williams statement.

In addition to his role at Sherwin-Williams, Morikis serves on the Boards of Fortune Brands Home & Security Inc., the Joint Center for Housing Studies Policy Advisory Board at Harvard University and the University Hospital Ahuja Medical Center.

Morikis holds bachelor's degrees in business administration and psychology from Saint Joseph's College in Rensselear, Ind., and a master's degree in business from National Louis University in Evanston, Ill.

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Survey Digs Into Infrastructure Spend *(Oct. 22)*

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Are U.S. leaders taking the state of American infrastructure seriously? More than 60 percent of Americans say "no," according to a recent survey conducted by AAA.

Participants in the survey overwhelmingly indicated that maintenance and repair of roads and bridges should be a top priority for funding. Adding and expanding travel lanes ranked highly, as well.

"Americans rely on our nation's roads and bridges every day, yet Congressional inaction has led to longer commutes, more potholes and unsafe conditions," Marshall Doney, AAA president and CEO, said in the company's announcement of its findings.

More than 60 percent of Americans say the federal government should be doing more for the nation's infrastructure, according to a recent survey conducted by AAA. "Motorists are dissatisfied that our national leaders repeatedly have failed to meet the basic needs of drivers across the country," Doney added.

According to the survey results, the majority of Americans — 70 percent — believe the federal government should invest more than it does now for roads, bridges and mass transit systems. Additionally, only 38 percent of those queried believe Congress is working to ensure that our roads, bridges and transit systems will meet the needs of the nation.

PSN TOP 10 *(as of Oct. 31)*

1. 'Major Deficiencies' Found in Big Dig
2. Construction Site Water Tank Ruptures
3. Painter Fired from NASA Files Lawsuit
4. Sherwin-Williams: Q3 2015 Sales Up
5. Bridge Collapse Injures 9 Workers
6. Navy Science Team Advances Coatings
7. Sherwin-Williams Announces New CEO
8. PPG: Record Income in Q3
9. Construction Bridge Falls on Highway
10. Golden Gate to Get a 'Safety Net'

WHAT'S GOT US TALKING

(PaintSquare News Weekly Poll, Oct. 25-31)

Some roadways, like the new LBJ Expressway in Dallas, are varying toll rates, based on traffic volume and peak usage times, as a means to repay private investors in public-private partnership (P3) highway projects. Do you think this is a wise move?

YES, the investors have to make their money back somehow, so that's fine. **15%**

YES, I agree that investors have to make a profit, but I don't like that the toll lanes change prices throughout the day based on traffic; that's a penalty to the drivers. **22%**

NO, because the investors are making interest on their bonds, so cut the additional fees. **22%**

NO, I do not believe we should have public and private money mixed together for P3 projects. **41%**

Car F.: *"P3 is an elegant way for private syndicates to extricate money from the 'socialist' government purse, while at the same time expounding on the virtues of private initiative, who could not exist otherwise without the infusion of public money on large-size public projects."*

M. Halliwell: *"I think P3s have their place and can be a valuable tool. In days where the government balance sheet is tight, it can be a way to get important infrastructure projects done."*

Tom Schwerdt: *"I actually support dynamic pricing — when traffic is heavy it can dramatically improve throughput (vehicles per hour) by avoiding gridlock. The original study in California showed that throughput for two dynamically priced lanes was noticeably better than three "free" lanes on the same corridor . . . Because of the increased throughput of the dynamic tolled lanes, the traffic flow on the free lanes actually improves as well."*

On Coating of Dissimilar Metals in Storage Tanks

WHAT COATING PROBLEMS ARE LIKELY IN STORAGE TANKS THAT HAVE DISSIMILAR METAL SIDES AND FLOORS?

B. Brown

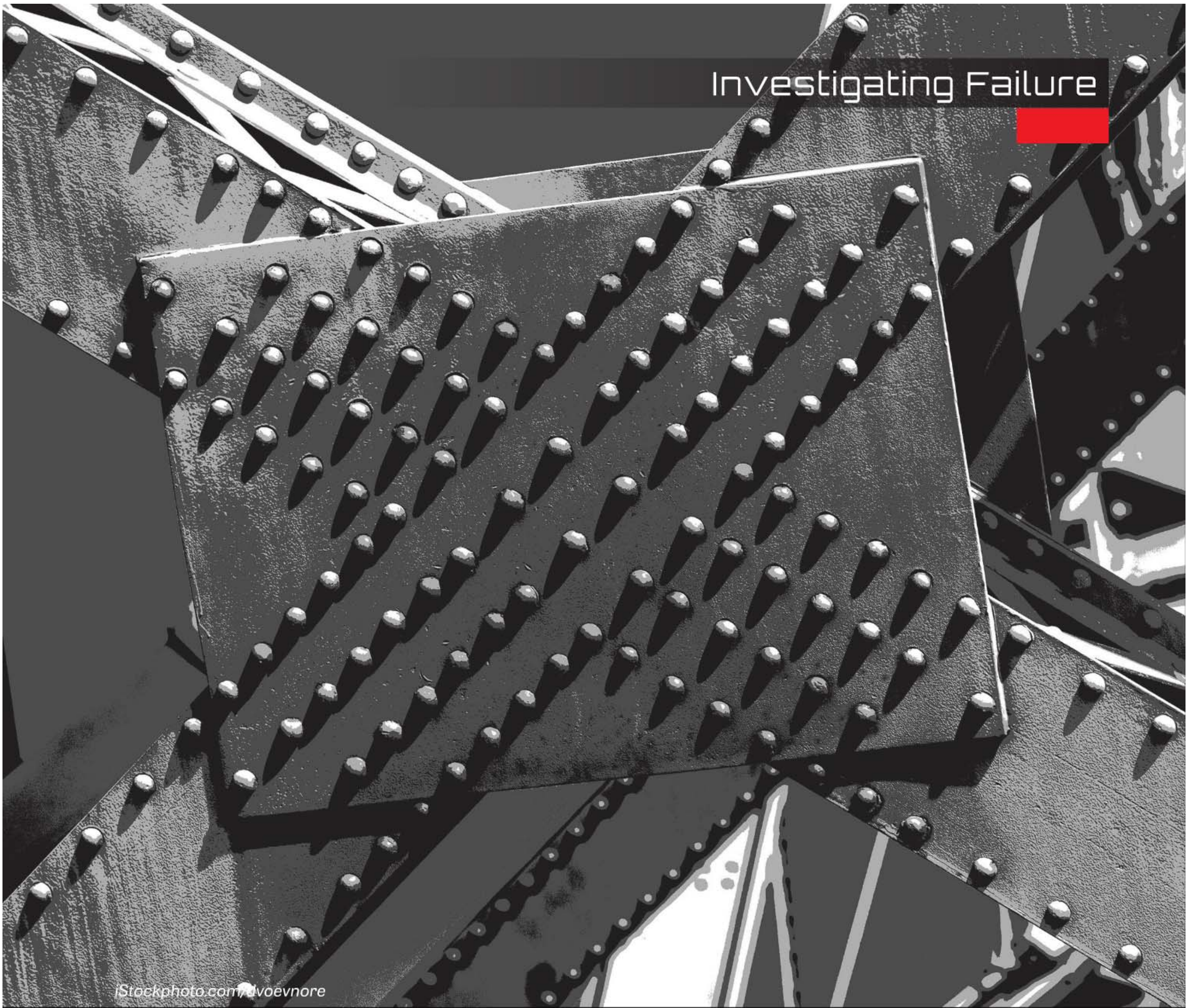
The better you define your question, the more likely you are to receive a good answer to your problem. "Dissimilar metal" could be rolled plate and forged components all made of carbon steel. I'll suppose the dissimilarity is more varied such as carbon steel and austenitic stainless or maybe a copper alloy. The most obvious would be that anchor profile will vary, given that each metal is subjected to identical surface preparation conditions. Although the stainless is likely to be of similar hardness to the carbon steel, stainless work hardens as it is abraded and typically, a shallower profile depth is produced with stainless. A harder, sharper abrasive might therefore be chosen for abrasive blast-cleaning the stainless. A zinc primer would probably be a poor idea for coating that stainless, but then I did start by saying we have been provided almost no detail regarding what you plan to coat, how you intend to clean and prepare the surfaces or what you plan to coat these surfaces with.

William Slama
International Paint/Ceilcote Products

Going back to "Thin Coatings /Metallurgy 101," this was always a no-no. That was because of the differential galvanic effect making the carbon steel anodic to the more noble alloy. So, if there was even one pinhole near the stainless, the corrosion would quickly "drill" through the steel. Determining factors include the area of the alloy, the distance to the pinhole and the conductivity of the solution contained. Even early on, most specifiers solved this by requiring that the alloy also be coated over to electrically insulate the alloy to eliminate the galvanic potential. Later, when high-build linings were used to line vessels to protect against challenging chemical and thermal environments, this effect was not noticed. That was because the high-build linings were high-voltage tested and could not have pinholes. Moreover, the thicker linings provided high electrical resistance through the lining, so the slight voltage difference was not a problem. In many vessels, it was found to be more reliable to use alloy support brackets and other internals than to try to coat those surfaces for protection. The procedure presently used is to bring the polymer lining a few inches over onto the alloy surface. That process has been used successfully for many decades.

Ernie Johnson
Brock Group

You can answer this where all can understand it. When a certain coating is chosen for a tank, one of the main concerns is what product is the tank going to hold and what metal is the tank. If you use, say, an epoxy for a steel tank and if by chance it also has stainless or galvanized, sooner or later the paint will peel off the stainless or galvanized. The only question is when, and that is determined by how large the area is that's not intended for the coating you're using and how much extra or special prepping you did to those areas, such as acid wash the galvanize. No matter, sooner or later the coating will fail.



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The Mystery of the Failing Bridge Paint

BY DWIGHT G. WELDON, WELDON LABORATORIES, INC.

Faced with a tight budget, a municipality in a midwestern state decided to overcoat the deteriorating paint system on an old bridge, rather than bear the expense of blast-cleaning the structure and applying a new coating system.

Images courtesy of the author unless otherwise noted.

Fig. 1: The calcium sulfonate structure.

Fig. 2: The back side of the white intermediate coat which disbonded from the red primer. Other than one or two tiny specks of red primer, the back side of the white coat is clean and smooth.

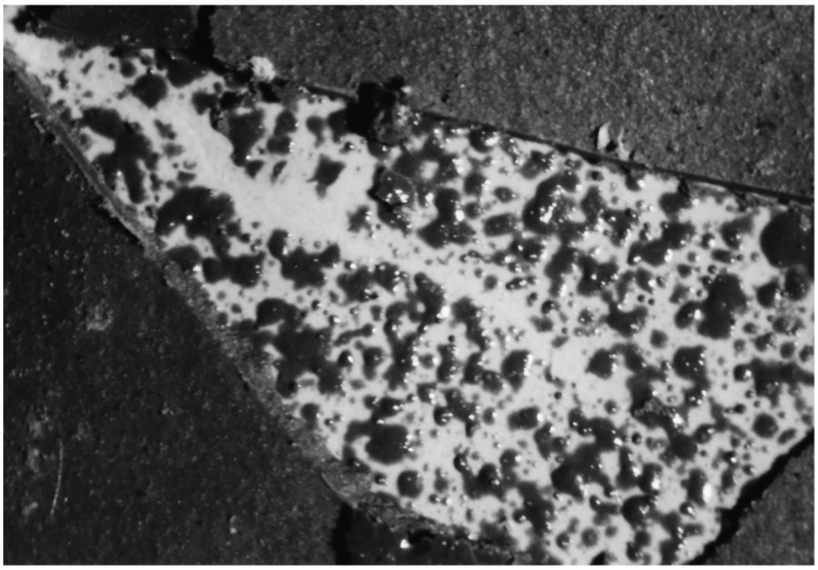


Fig. 3: This image shows globules of brown overspray on the front side of the white intermediate coat after peeling off the brown topcoat. Not only does the brown topcoat not stick to the white intermediate coat, it does not stick to its own overspray.

Table 1: Adhesion Testing Using ASTM D3359 Method B

Coating System	Recoat Time	Intercoat Adhesion
Primer/intermediate coat	2 hours	OB (almost 100% failure even beyond crosshatch area)
Primer/intermediate coat	1 day	OB (almost 100% failure even beyond crosshatch area)
Primer/intermediate coat	1 week	OB (almost 100% failure even beyond crosshatch area)
Intermediate coat/topcoat	2 hours	OB (almost 100% failure even beyond crosshatch area)
Intermediate coat/topcoat	1 day	OB (almost 100% failure even beyond crosshatch area)
Intermediate coat/topcoat	1 week	OB (almost 100% failure even beyond crosshatch area)

With input from an engineering firm, the municipality developed a specification that involved pressure washing of the existing alkyd coating system to remove any poorly adherent coating, along with power tool cleaning to remove any small areas of corrosion. Any areas of bare steel were to be touched up with one coat of red primer followed by a white intermediate coat and then the whole structure was to receive a full coat of brown paint. All three coats were calcium sulfonate alkyds and had the same composition except for pigmentation.

Calcium sulfonate coatings are often used on overcoating projects because they tend to be tolerant of marginally prepared surfaces, they are relatively soft and flexible and they impart less curing stress than do certain other coating types. This in turn puts less stress on old paint systems which might otherwise be prone to fracturing or disbonding. The concept has been used successfully many times.

The Coating Material

The distinguishing feature of calcium sulfonate alkyds is the calcium sulfonate structure shown in Figure 1. It essentially consists of a calcium aryl sulfonate compound, with a long chain aliphatic hydrocarbon group (the "R" group in Figure 1) attached to the aromatic ring, complexed with numerous (the "n" in Figure 1) calcium carbonate molecules which can be as high as about 20.

The product data sheet for the calcium sulfonate coating listed a thickness of 4-to-6 mils, and recommended a "wet-on-wet" approach, with a recoat time of two hours. However, the literature also stated that there was no maximum recoat window. In practice, the two-hour, wet-on-wet approach was not used. This was because there was a third-party inspection firm on the project who insisted

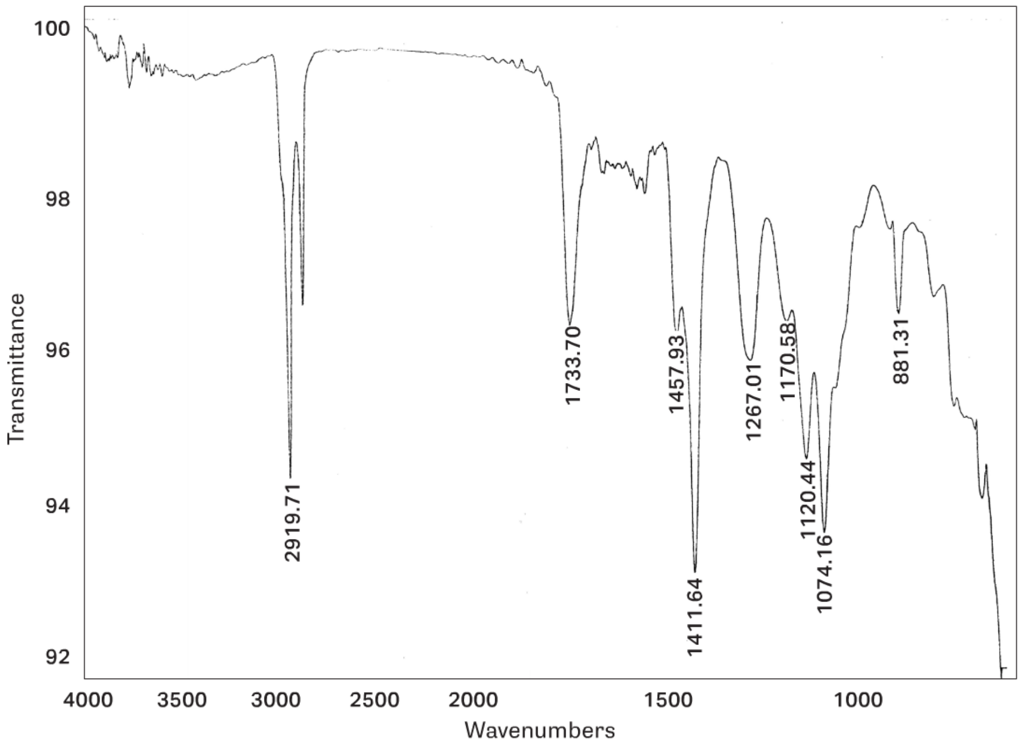


Fig. 4: Infrared spectrum (via ATR) of control sample of calcium sulfonate alkyd.

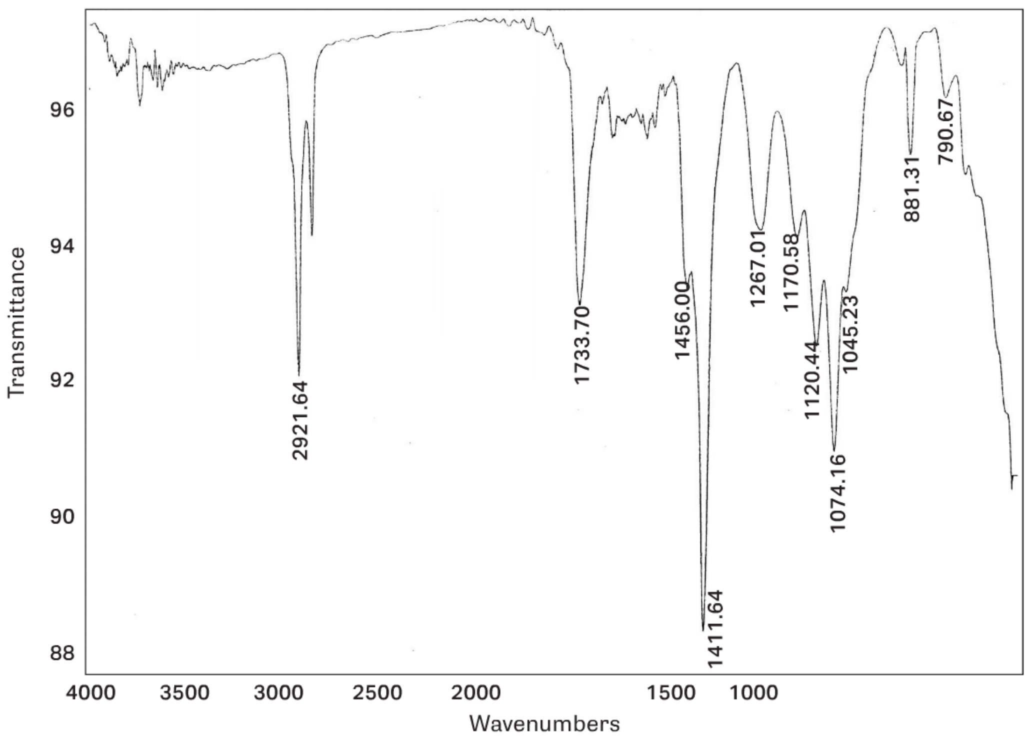


Fig. 5: Infrared spectrum (via ATR) of back side of failing jobsite paint chip.

that dry film thickness (DFT) readings be taken on each coat. Since the calcium sulfonate coatings were not dry enough in two hours to get accurate DFT measurements, the recoat windows were typically one or two days.

After about six months, some minor flaking of the paint was noted. After a year's time the flaking and peeling had become a major problem and various samples were submitted to the laboratory for analysis. These samples consisted of disbonded paint chips, as well as quantities of all three coating materials used at the jobsite. According to the client, failure was only occurring between coats of the recently applied calcium sulfonate. There was no failure of the red calcium sulfonate primer from bare steel, and no failure of the brown calcium sulfonate topcoat where it had been applied directly over the old, adherent alkyd topcoat.

Sample Inspection

The first step in the laboratory was a visual and microscopic examination of the failing paint chips. The first chip examined was about 2-by-4 inches in size and consisted of two coats: a white coat about 6-to-7 mils thick, and a brown topcoat about 4-to-5 mils thick. The white coat apparently corresponded to the intermediate coat, which had disbonded from the red primer. Other than one or two small specks of red primer, the back side of the white coat was clean and smooth (Fig. 2, p. 16).

Additional probing of Sample No. 1 with an X-acto knife revealed an interesting finding. With care, the brown topcoat could be easily peeled away from the white intermediate coat. When this was done, both the back side of the brown topcoat and the front side of the white intermediate coat were clean and smooth. So, not only did the intermediate coat have very poor adhesion to the red primer, but the topcoat had very poor adhesion to the intermediate coat.

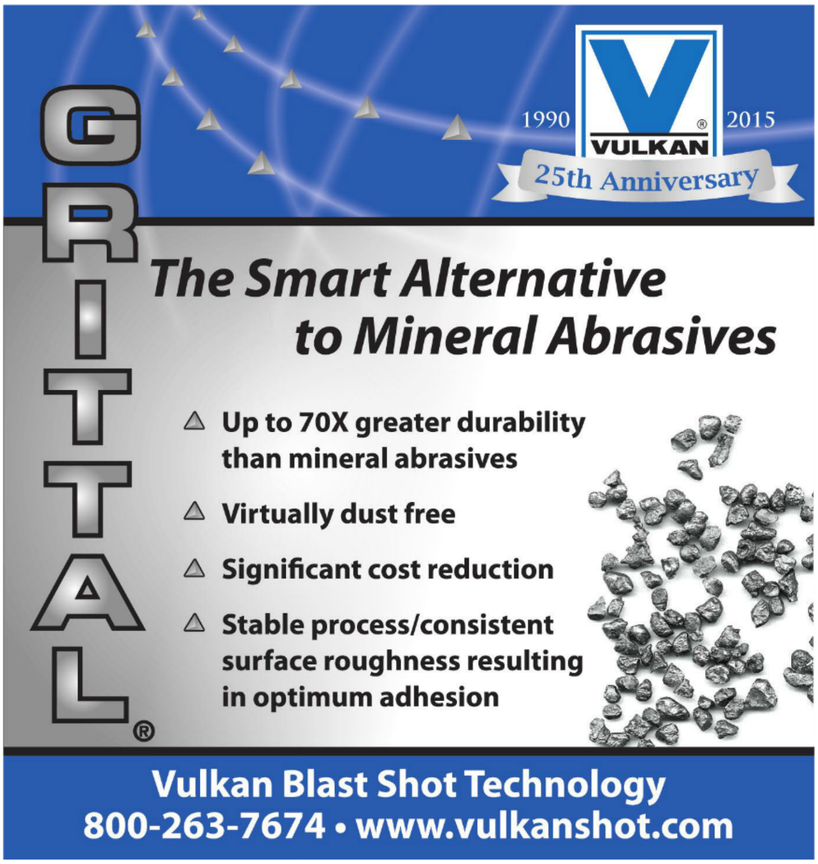
A second paint chip sample was examined (Sample No. 2), which had the same general appearance and characteristics as Sample No. 1, although the white intermediate coat was thicker than specified (8-to-9 mils versus the specified 4-to-6 mils). Once again, the back side of the white coat was clean and smooth and once again, careful probing showed that the brown topcoat could be easily peeled from the white intermediate coat. However, when this was done, there were several globules of brown overspray on the exposed front surface of the white intermediate coat and corresponding pockmarks on the back side of the removed topcoat (Fig. 3, p. 16). Hence, not only did the brown topcoat not stick to the white intermediate coat, it did not even stick to its own overspray. Furthermore, the brown overspray globules themselves could be easily flaked off of the surface of the white coat. It appeared that, as the author once heard someone say, "This paint doesn't stick to anything!"

A third sample was examined, which consisted only of brown topcoat that had apparently disbonded from the white intermediate coat. The back side of this sample was clean and smooth except for some pockmarks, likely where it had disbonded from overspray globules much like Sample No. 2. The cross section showed a single brown coat, 5-to-6 mils thick.

A few other chips were examined, which basically showed the same features as the samples previously described. Although there were a few exceptions, the samples showed that the coatings had generally been applied at the specified thickness. There was also no evidence that the coatings had been applied over dirt or any other type of visual contamination.

Laboratory Testing

The next step in the investigation consisted of infrared spectroscopy



(see the author's column in *JPCL*, December 2014), using both the potassium bromide (KBr) pellet technique, and an attenuated total reflectance (ATR) technique.

Spectra obtained via KBr pellets are characteristic of the bulk composition of a sample. These spectra showed no differences in bulk composition between failing samples of bridge paint and liquid control samples of these paints applied in the laboratory.

ATR spectra are sensitive to the surface composition of a sample. They are often used when one is investigating the possibility of some type of surface contamination, such as oil or a blush. ATR spectra were obtained from the back side of failing chips and compared to a spectrum of a control sample (Figs. 4 and 5, p. 18). The spectra of the jobsite samples were essentially identical to the spectra of the control samples indicating that the poor adhesion was not due to any organic contamination.

Analysis

So, where are we in the investigation? We know that the calcium sulfonate coatings adhere well to bare steel and to the old, existing alkyd topcoat on the bridge. We know that the failure is between the various coats of the calcium sulfonate, and that the brown calcium sulfonate topcoat doesn't even stick to its own overspray. These facts alone are enough to suggest that the problem is not one of painting over contamination, since it is unlikely that there would have been contamination between all these coats of paint. This was confirmed by microscopic observation and infrared spectroscopic analysis, which showed no visual contamination and no "invisible" organic contamination. We also know that paint thickness is not a cause, since most of the samples showed that the coats of paint were applied in the correct thickness range.

One area of suspicion is recoat time. The manufacturer's product data sheet recommended a "wet-on-wet" approach, with a recoat time of two hours. Because of the desire of the inspection company to get accurate DFT readings, the actual recoat times were typically one or two days. In spite of the wet-on-wet recommendation, the product data sheets stated that there was no maximum recoat time. This seemed confusing and almost contradictory. Hence, some panel testing seemed to be in order.

Further Investigation Warranted

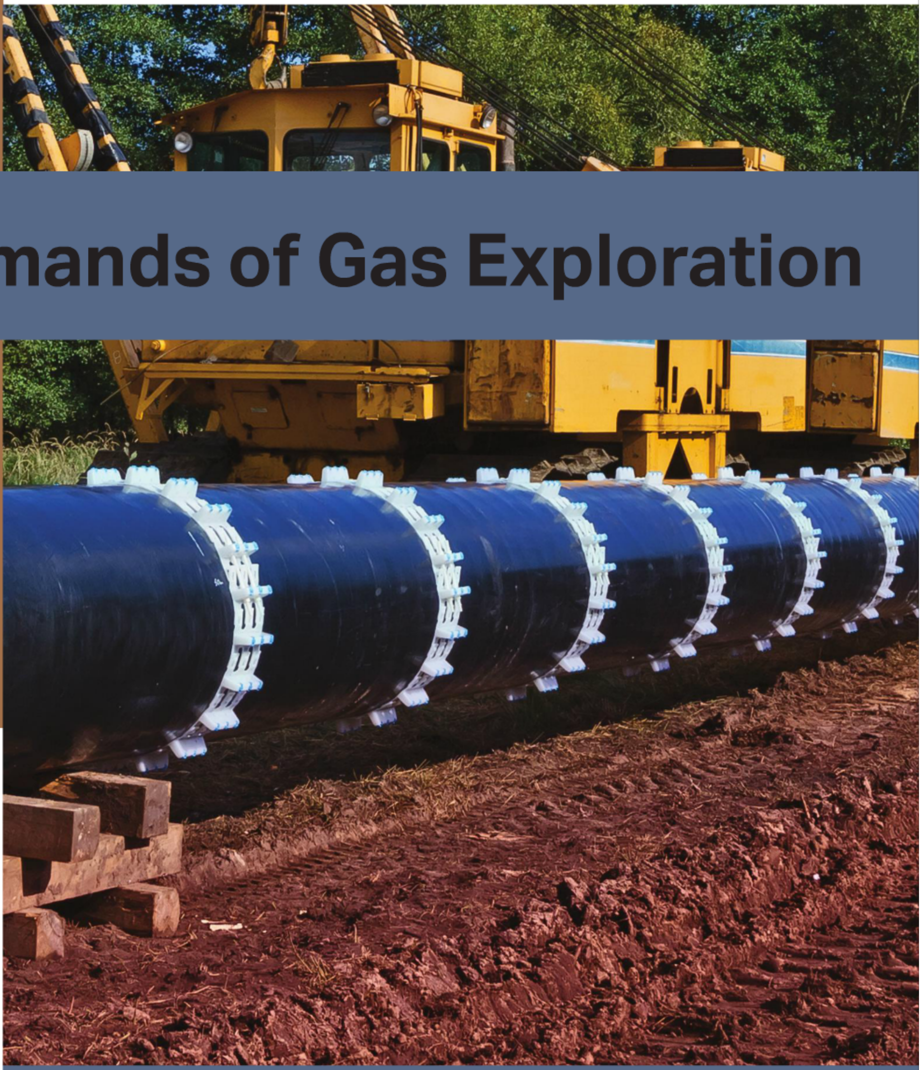
Some of the test panels were painted with the red primer and the white intermediate coat, while others were painted with the white intermediate coat and the brown topcoat. Recoat times were two hours, one day, and one week. After allowing all of the panels to cure for at least one week they were evaluated for tape adhesion (ASTM D3359, Method B). This method involves using a knife to scribe a cross-hatch pattern on the panel and then applying a special pressure-sensitive adhesive tape. The tape is then rapidly removed and the amount of coating detachment is assessed in accordance with the method's visual rating system. This ranges from a 5B for no removal of coating, down to a 0B for 65-percent or greater removal of coating. The test results are displayed in Table 1 (p. 16).

Conclusion

The author must admit that he was about ready to blame the failure on the inspection company's insistence to wait one or two days before recoating instead of adhering to the coating manufacturer's recommendation of a two-hour, wet-on-wet approach. However, as the test results clearly show, it would not have made a difference. None of the calcium sulfonate coatings stuck to one another, even with the recommended two-hour recoat time. So, it's not quite true to say that, "This paint doesn't stick to anything." It just doesn't stick to itself. The blame for this failure clearly lies with the coating manufacturer, and not the applicator or specifier.

Meeting Demands of Gas Exploration

THE EVOLUTION OF PIPELINE COATINGS



By E. Bud Senkowski, P.E., P.C.S., KTA-Tator, Inc.

Fracking (hydraulic fracturing) has marked a new era of natural gas exploration. Through this technique, huge deposits of oil shale like the Marcellus and Utica, which extend from the Appalachians into Canada, are now producing enough gas to meet North America's needs for the next 14 years. This boom in gas exploration has opened up new markets for pipeline and joint coating materials as estimates of pipeline construction in Pennsylvania alone are in the range of 12,000 to 27,000 miles by the year 2030.

This article will describe the coating materials, surface preparation requirements and application methods used to protect gas pipelines. It will also provide valuable insight into the types of polymer-based coatings that are both cost-effective and have a high level of acceptance in the gas pipeline industry.

Why Are Pipeline Coatings Necessary?

Corrosion is the greatest danger to buried steel pipeline, and uncontrolled corrosion of the pipe wall leads to leaks, service interruptions and even explosions. Interstate pipelines are regulated by state or Federal agencies, primarily the Departments of Transportation (DOTs). At a minimum, these agencies mandate corrosion protection through the application of protective coatings and the installation of supplemental cathodic protection. However, intrastate pipelines are not regulated by the DOTs, and the condition of the coated pipe as it is buried in a trench must be carefully considered.

The History

1930 to 1950

The first steel pipelines were in the ground in the late 1800s, and owners realized then that burying steel pipe without additional corrosion protection was not an acceptable long-term strategy because corrosion quickly caused pipeline leaks. From 1930 to 1950, industrialization in the Midwest and Northeast increased demand for energy, and oil and gas pipelines that originated in the Texas oil fields and refineries fulfilled a large portion of this demand. Their reliability depended on the effectiveness of corrosion control measures. As the pipeline industry matured, so did the technology of protective coatings, and one of the early innovations was the use of a built-up system where the hot products (asphalt or coal tar) were reinforced by application of a tar-saturated felt mat that was worked into the hot matrix.

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The system was completed with a spiral wrap of kraft paper. Coating application typically took place over the trench. For many years, the built-up coal tar and asphalt coatings were the predominant systems used on buried pipelines. Another popular system was based on using petroleum-based wax coating reinforced with fiber mesh, and these two systems accounted for nearly all of the protective coatings applied to buried pipe from 1930 through 1950.

The first large-scale pipeline project in the U.S. was the "Big Inch" (24-inch) crude oil and the "Little Big Inch" (20-inch) petroleum products pipelines project, constructed from August 1942 through August 1944. The federal government funded the project through a quasi-public company called "War Emergency Pipelines, Inc." At the time, the "Big Inch" was the longest and most expensive pipeline in the world. The impetus for the project was the German submarine menace that resulted in the sinking of hundreds of tankers as they attempted to transport crude oil and gasoline over a distance of 1,475 miles, from Baytown and Beaumont, Texas to Phoenixville, Pa. and Linden, N.J. The pipeline steel was seamless with a pipe-wall thickness of 3/8-inch. It was machine-wrapped over-the-ditch with a three-part coating system consisting of a hot-applied coal tar primer, fiber-reinforced coal tar tape and a reinforced fiber outer wrap.

1950 to 1970

By the mid-1950s, new hydrocarbon polymers were introduced into pipeline coating products to improve performance in the underground environment. Epoxy resins were formulated using coal tar-based pigments to make a liquid-applied pipeline coating. Coal tar epoxy exhibited superior resistance to penetration by water. Over the same period, application methods also changed. Systems like the multiple-layered coal tar tape, applied hot and over-the-trench, gave way to cold-applied, prefabricated tapes which used adhesives to bond to the pipe surface (Fig. 1, p. 28). These tapes used advanced polymers like vinyl and polyethylene, with butyl rubber adhesives. They were flexible, tough and highly resistant to water penetration. The 1960s also saw the introduction of fusion-bonded epoxy (FBE), which would eventually replace many of the earlier pipeline coating systems.

The Evolution of Pipeline Coating Materials

Today, pipeline coatings have evolved from basic, single-material products like coal tar or asphalt. They now consist of mill-applied products that use epoxy primers in conjunction with overwraps of various layered polymers. When used in combination, these composite coatings have better physical durability, thermal resistance and insulation properties than the earlier coating materials. Today's pipeline coatings utilize a variety of materials that are field-applied, liquid materials or systems pre-fabricated at a coating mill. Figure 2 (p. 30) displays the most commonly used pipeline coating materials.

Field-Applied Pipeline Coatings

Liquid Epoxy

Liquid epoxy is a copolymer that is formed by the chemical reaction of an epoxy resin (part A) and a hardener or catalyst (part B). When the two are mixed together, a chemical reaction converts them to a hard coating. After mixing, the epoxy can be applied by brush, roller or spray.

Liquid epoxy is primarily used as a field-applied coating to cover girth welds, fittings and valves, as well as to perform field rehabilitation of short sections of pipe. It is also used as additional protection at the soil-to-air interface where buried piping transitions to atmospheric exposure (Fig. 3, p. 30).

The applied thickness of liquid epoxy coatings will depend upon the solids content and the number of coats applied to the steel. Epoxy applications for pipeline work are in the range of 20-to-35 mils. Once full cure is achieved, the epoxy product becomes a thermoset coating, meaning it is insoluble in solvents and will not soften when heated. However, when heated above 250 F, the coating will decompose (Table 1, p. 26).

Coal Tar Epoxy

Coal tar epoxy (CTE) is a variation of liquid epoxy where some of the mineral fillers have been replaced with semi-liquid coal tar pitch. CTE also cures through a reaction of resin and hardener (parts A and B) to form a thermoset coating that is typical of all chemically-cured epoxy materials.

As with liquid epoxy coatings, the applied thickness of coal tar epoxy coatings will depend upon the solids content and the number of coats applied to the steel. CTE applications for pipeline work are typically in the thickness range of 15-to-35 mils (Table 2, p. 26). Coal tar epoxy has a relatively slow cure time. At ambient conditions (for example, 75 F), it will require five to seven days to fully cure. In some cases, force curing at 150 F can reduce the cure time to 8 hours.

Liquid Polyurethane

Liquid polyurethane is a hydrocarbon polymer formed by a chemical reaction between a polyol (resin) and a hardener (catalyst). Polyurethane is a chemically cured polymer. It is fast setting and the types used as pipeline coatings are typically applied using plural-component spray equipment.

Polyurethane has a temperature resistance of 235 F. It has excellent flexibility and good resistance to abrasion, impact and mechanical damage. It exhibits superior resistance to water penetration and most hydrocarbon solvents. It is a 100-percent-solids material that can be rapidly applied to reach film builds in the 15-to-50-mil range (Table 3, p. 28). Because of its fast-setting properties, polyurethane can be field-applied for both the rehabilitation of pipeline sections and as a coating for girth welds. The 100-percent-solids polyurethane used for buried piping is a different type of polyurethane than is used as a finish coat in non-pipeline, atmospheric service.

Surface Preparation

The minimum level of surface preparation for most liquid epoxy products cannot be achieved using hand or power tools. The pipe surface must be cleaned with air-driven abrasive to achieve SSPC-SP 10/NACE No. 2, "Near White Blast Cleaning" removal of all adherent mill scale and rust with only a maximum of 5 percent of staining remaining. Failure to reach this end condition may result in poor adhesion of the epoxy to the steel.

Table 1: Characteristics and Limitations of Liquid Epoxy

Thickness Range, Mils	20-35
Electrical Resistance	Excellent
Water Penetration Resistance	Excellent
Heat Resistance	230 F
Solvent Resistance	Excellent
Impact Resistance	Good
Bendability	Good
Abrasion Resistance	Good
Cathodic Disbondment Resistance	Excellent
Mill Application	No
Field Application	Yes

Table 2: Characteristics and Limitations of Coal Tar Epoxy

Thickness Range, Mils	15-35
Electrical Resistance	Excellent
Water Penetration Resistance	Excellent
Heat Resistance	350 F
Solvent Resistance	Fair
Impact Resistance	Good
Bendability	Good
Abrasion Resistance	Good
Cathodic Disbondment Resistance	Excellent
Mill Application	Yes
Field Application	Yes

Coal tar epoxy also requires surface preparation with air-driven abrasive. Depending upon the specification or product requirements, the pipe surface must also be cleaned to SSPC-SP 10/NACE No. 2 or SSPC-SP 6/NACE No. 3, "Commercial Blast Cleaning" where all adherent mill scale and rust are removed with staining on no more than 33 percent of the surface area.

Application Considerations

When coating work is performed in the field on an operating pipeline, the temperature of the gas and carrier pipe may be below the air temperature. These conditions may lead to the formation of condensation on the pipe surface. There are liquid epoxies available that can tolerate application to damp surfaces and actually displace a water layer as they are rolled onto the pipe surface. Despite the availability of these products, it is more advantageous to coat dry pipe.

Heat may be used to force cure a liquid epoxy in order to increase production rates on over-the-trench work. Induction heating can be used to heat the cleaned steel prior to coating application and to accelerate

Table 3: Characteristics and Limitations of Polyurethane

Thickness Range, Mils	15-50
Electrical Resistance	Excellent
Water Penetration Resistance	Excellent
Heat Resistance	235 F
Solvent Resistance	Good
Impact Resistance	Good
Bendability	Good
Abrasion Resistance	Good
Cathodic Disbondment Resistance	Excellent
Mill Application	Yes
Field Application	Yes

Table 4: Characteristics and Limitations of Fusion-Bonded Epoxy

Thickness Range, 1-Layer, Mils	12-18
Thickness Range, 2-Layer, Mils	28-36
Electrical Resistance	Excellent
Water Penetration Resistance	Excellent
Heat Resistance	250 F
Solvent Resistance	Excellent
Impact Resistance	Good
Bendability	Good
Abrasion Resistance	Good
Cathodic Disbondment Resistance	Excellent
Mill Application	Yes
Field Application	Yes

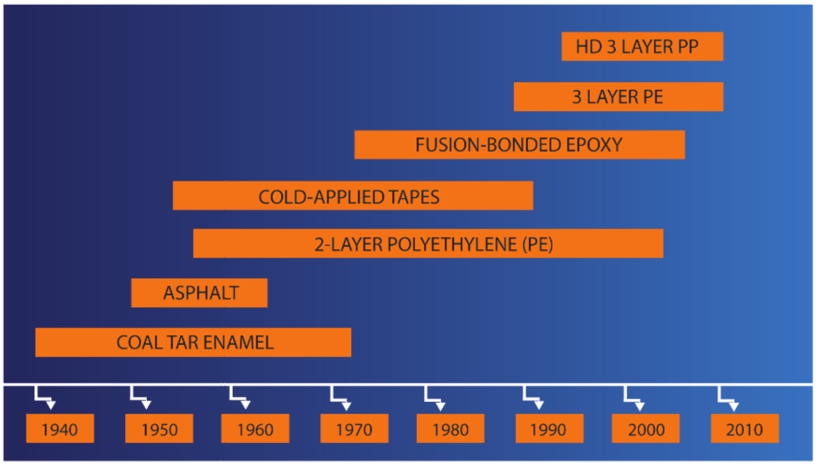

Fig. 1: Pipeline coating developments, 1940 to present. Figure courtesy of the author.

curing afterwards. Safety precautions are required any time heat is used in combination with coatings.

Mill-Applied Pipeline Coatings

Almost all of the new pipeline construction projects use pipeline sections that have been coated in a mill and shipped to the construction site. The reasons for choosing mill application over field application are production efficiency, a controlled application environment, better access for application and quality control, and the ability to apply complex coating systems that cannot be applied in the field.

Coating systems applied at the mill include multi-layer polyethylene, multi-layer polypropylene, single and multi-layer FBE, liquid epoxy, polyurethane, and coating systems encased in a weight coat of concrete. These materials may be selected to maximize properties such as adhesion to the steel, mechanical resistance and resistance to water penetration.

Application Considerations

Methods to apply pipeline coatings in a mill are highly specialized processes that include application by crosshead extrusion, side extrusion, electrostatic spray and plural-component spray.

Crosshead Extrusion

Crosshead extrusion is a process whereby a polymer is squeezed onto the steel pipe as it is passed through a metal die. Both the

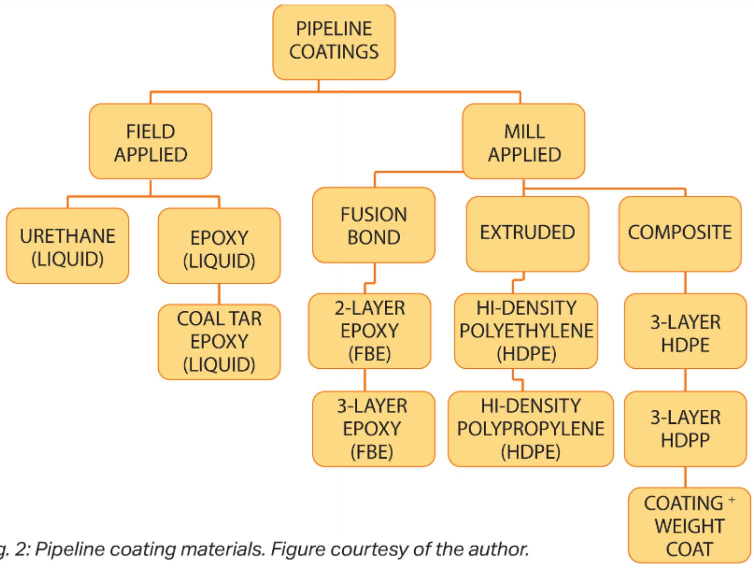

Fig. 2: Pipeline coating materials. Figure courtesy of the author.

Fig. 3: Air to soil transition on a pipeline run. © iStockphoto.com/drnadig

die clearance and speed of the pipe through the die determine the thickness of the coating layer. Becausee many molten polymers do not adhere well to bare steel, the coating is extruded over an elastomeric adhesive to achieve bonding. Coatings applied by crosshead extrusion are a continuous layer and have no seams. This application process is used for pipe in the diameter range of 2-to-20 inches.

Side Extrusion

Side extrusion is for coating pipe in the range of 4-to-145 inches in diameter. In this process, cleaned and adhesive-primed pipe travels spirally through the extruder where several layers of molten polymer are applied in flat sheet form and squeezed against the pipe by a silicone rubber roller. The roller improves interlayer adhesion and eliminates air entrapment between the layers. As the spiral seams are fused together, side extrusion provides a uniform coating with virtually no distinction or separation between layers.

FBE Process

FBE is typically applied at a pipe mill. The coating process involves cleaning the steel pipe surface with abrasive grit in a centrifugal blasting cabinet to a cleanliness level of SSPC-SP 10/NACE No. 2. Induction or oven heating is used to heat the cleaned pipe to the 356-to-482 F range before it is sent through a fluidized bed of suspended epoxy particles. The particles melt and fuse on contact with the heated pipe. Curing (cross-linking) of the epoxy occurs within several minutes and is followed by a water quench. The FBE coating thickness is controlled by the speed of the pipe's movement through the fluidized powder-coating bed.

FBE can be mill-applied as a one- or two-layer pipeline coating. Single-layer FBE is applied in the range of 12-to-16 mils. A dual-layer process can be used where two consecutive FBE layers are applied to the heated pipe. The inner layer, at 12-to-16 mils dry film thickness (DFT) provides corrosion protection to the steel pipe. While it is still soft, a second or outer layer at 30-to-36 mils DFT is applied as an additional barrier coat and provides abrasion resistance (Table 4, p. 28).

Table 5: Characteristics and Limitations of High Density Polypropylene

Thickness Range, Mils	40-50
Electrical Resistance	Excellent
Water Penetration Resistance	Excellent
Heat Resistance	230 F
Solvent Resistance	Excellent
Impact Resistance	Excellent
Bendability	Excellent
Abrasion Resistance	Excellent
Cathodic Disbondment Resistance	Good
Mill Application	Yes
Field Application	Yes

Coating Types

Polyethylene Pipeline Coatings

Polyethylene (PE) is the starting point for many pipeline coatings. PE is a thermoplastic polymer. Unlike the thermoset epoxy coatings previously described, a polyethylene will soften with heat and has a melting point in the range of 221-to-266 F. High-density polyethylene (HDPE) is typically used for extruded pipeline coatings.

HDPE is a mill-applied coating whereby the molten polymer is extruded onto the steel pipe as it is passed through a metal die. Manufactured as a two-layer product, it consists of 20-to-30 mils of polyethylene extruded over 10 mils of rubberized asphalt adhesive.

High-Density Polypropylene

The manufacture of high-density polypropylene (HDPP) is quite similar to that of HDPE. It is a thermoplastic polymer that will soften with heat. Depending upon the degree of cross branching, polypropylene has a melting point in the range of 320-to-340 F, with better heat and impact resistance than HDPE.

For pipeline application, HDPP is used as an extruded pipeline coating. In the 1960s, application of HDPP pipeline coating was as a seamless 40-to-50-mil product when extruded over an adhesive primer. HDPP has better high-temperature resistance than any other polymer in use as a pipeline coating. It has superior mechanical resistance to penetration, impact and abrasion. HDPP is the material of choice when resistance to mechanical damage is an important design requirement. The water penetration resistance of HDPP is slightly better than HDPE (Table 5, p. 32).

Composite Pipeline Coatings

Over the past 20 years, technological advances in material fabrication have resulted in a new class of pipeline coatings with enhanced physical endurance, thermal resistance, and resistance to water penetration and cathodic disbondment. The systems are called composites. They represent combinations of existing polymer materials, formerly used in a single-layer configuration, that have been combined to produce improved multi-layer pipeline coating systems.

Three-Layer Polyethylene

A three-layer-polyethylene (3LPE) system is a multi-layer coating composed of an FBE base coat, a copolymer adhesive and an outer layer of side-extruded HDPE.

The tough outer layer of HDPE protects the coating system during transportation and installation. Lowering-in damage is reduced and protection against abrasive soil conditions is maximized. HDPE has good water penetration resistance. The FBE primer develops an excellent bond to the steel and has superior resistance to cathodic disbondment. The coating system can endure operating temperatures up to 185 F but is available only as a mill-applied system (Table 6).

Three-Layer Polypropylene

A three-layer polypropylene (3LPP) system is a multi-layer coating composed of an FBE primer, a copolymer adhesive and an outer layer of side-extruded HDPP — similar to the 3LPE previously described, but with an HDPP outer layer in place of the HDPE.

The FBE primer component of the coating system provides excellent adhesion to steel and imparts long-term corrosion resistance. FBE also has superior resistance

Table 6: Characteristics and Limitations of 3-Layer Polyethylene

Thickness Range, Mils	45-95
Electrical Resistance	Excellent
Water Penetration Resistance	Excellent
Heat Resistance	185°F
Solvent Resistance	Excellent
Impact Resistance	Excellent
Bendability	Excellent
Abrasion Resistance	Excellent
Cathodic Disbondment Resistance	Excellent
Mill Application	Yes
Field Application	No

Table 7: Characteristics and Limitations of 3-Layer Polypropylene

Thickness Range, Mils	45-95
Electrical Resistance	Excellent
Water Penetration Resistance	Excellent
Heat Resistance	284 F
Solvent Resistance	Excellent
Impact Resistance	Superior
Bendability	Excellent
Abrasion Resistance	Superior
Cathodic Disbondment Resistance	Excellent
Mill Application	Yes
Field Application	No

to cathodic disbondment. The tough outer layer of HDPP protects the coating system pipelines during transportation and installation. Costly repairs from lowering-in damage are reduced, while in-ground protection against shear forces, chemicals and abrasive soil conditions are minimized (Table 7).

This mill-applied coating system can endure operating temperatures up to 185 F. Because it can withstand rough handling, 3LPP is a preferred system for offshore pipeline projects.

Abrasion-Resistant Coating Systems

Abrasion-resistant pipeline coating systems are manufactured to provide superior resistance to damage caused by rock-filled backfill and directional boring operations. Following are descriptions of the more common systems.

Polymer Concrete

Polymer concrete is a mixture of concrete aggregate and an epoxy binder. In a popular configuration it is used to protect the FBE on steel pipe when it is subjected to severe handling conditions during installation. Polymer concrete is a highly abrasion- and impact-resistant coating that provides a smooth surface to allow the pipeline to be pulled under the crossing in a slick-bore operation with much less drag resistance than conventional concrete. It can also be used as a rock shield. Polymer concrete can be sprayed onto the FBE-coated pipe in a thickness range of 20-to-125 mils.

Abrasion-Resistant Overcoating

Abrasion Resistant Overcoating (ARO) provides physical protection to FBE pipeline coatings. ARO is also an FBE product, but is an extremely hard and mechanically strong overcoating designed to protect the FBE basecoat from damage during pipeline directional drilling and boring. ARO also offers strong abrasion protection to coated pipe and pipe pilings installed in river crossings and rough terrain.

ARO is compatible with all FBE coatings and chemically forms a high-adhesive bond at the layered interface. The tough outer coating also retains a high degree of flexibility that exceeds specification limits of steel for field bending. One typical ARO system consists of an initial primer layer of 8-to-16 mils of epoxy covered with 20-to-35 mils of a higher-density epoxy. Liquid, 100-percent-solids epoxy ARO coatings can be spray-applied in the mill or in the field at a thickness of up to 60 mils.

Weight Coat

Anti-corrosion polymer pipeline coating systems can be augmented with an exterior layer of reinforced concrete of from 1-to-9 inches for buoyancy control. In this arrangement, the added exterior layer of concrete provides both negative buoyancy to sink the pipeline and mechanical protection for pipelines in deep-water marine and wet environments, such as tidal swamps, wetlands and rivers.

Conclusion

Nearly 80 years have gone by since the first rudimentary coating systems, utilizing coal tar and asphalt, were applied to underground pipelines to control corrosion. As time passed, the pipeline-coating industry has matured to the point where reliable coating materials are now available that can be applied at high-production rates in a coating mill with an equally high level of quality control. Depending upon the service requirements, coating materials like epoxy, polyethylene and polypropylene will be the building blocks for most of the pipeline coating demands brought about by the hydraulic fracturing process.

About the Author

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NONTOXIC BARNACLE ANTIFOULING

BY BRIAN GOLDIE, *JPCL*

Fig. 1: Lepadid (gooseneck barnacles, Lepas anatifera). Photo courtesy of Tom Page.

Biofouling occurs in all oceanic waters and in all seasons, although with a higher intensity in warm waters and in certain regional areas. Within a matter of hours, all submerged surfaces experience fouling, an accumulation of plants, algae, microorganisms and animals. Initially, polysaccharides and bacterial colonies create an organic biofilm (slime) that forms the breeding ground for species of algae and larger shell-covered invertebrates.

More than 4,000 different organisms are known to contribute to biofouling, which can significantly affect the drag on vessel hulls and other underwater surfaces, and cause energy loss for shipping. Among these species, barnacles have the largest and most detrimental impact on operations and maintenance. Barnacles, as shown in Figures 1 and 2 (p. 66), are sessile crustaceans, present in all marine and brackish waters. They settle on all hard surfaces, including ship hulls. Once settled, they attract other barnacles in the vicinity, which is why they're often seen in colonies.

The calcareous barnacle shells cause micro-turbulence along a ship's hull which increases drag dramatically, resulting in up to a 40-percent loss in energy efficiency. With rising fuel prices, ship owners must minimize unnecessary energy losses and use generated energy as efficiently as possible.

DEVELOPMENT DRIVERS

Producing surfaces with high resistance to marine fouling over time is therefore, the backbone of most hull-coating systems, and a high level of barnacle protection is the key to a successful antifouling paint. These coating systems have the potential to save thousands of dollars in fuel per day for a midsized vessel, as well as reduce greenhouse gas emissions, an increasingly important operational requirement.

The other driving force in the development of hull coatings is eco-toxicity. Until recently, the industry standard antifouling hull coatings were based on tin compounds. However, the release of these materials into the sea was shown to harm the marine ecosystem, particularly barnacles, and they were eventually banned by the International Maritime Organization (IMO). As a result, marine paint manufacturers began to seek alternative technologies, including self-polishing, copper-based systems and non-biocidal low-energy systems, known as foul-release systems. Nowadays all marine paint manufacturers offer a range of antifouling hull coatings, including the high-performance systems described briefly below.

BIOCIDE SELF-POLISHING SYSTEMS

These systems use the same technology as the previously successful tin-based systems, but with copper as the biocide. However, these coatings need the support of additional (organic) biocides to obtain the same performance as their tin-based predecessors. There are two main types of self-polishing systems: methyl acrylate (copper or zinc) and silyl acrylate, that is an acrylic polymer backbone with carboxylic side groups to which either metal or silyl compounds are chemically bonded. In sea water, hydrolysis takes place, breaking this bond and making the resultant carboxyl polymer soluble, resulting in the "polishing" action.

NON-BIOCIDAL FOUL-RELEASE SYSTEMS

Foul-release refers to antifouling hull coatings which do not employ biocides to control fouling, but instead prevent adhesion of fouling organisms by providing a low-energy, low-friction, smooth surface to which organisms have great difficulty attaching. These coatings do not completely stop fouling settlement but do provide a degree of self-cleaning when vessels are travelling at a minimum speed, the rate of which depends on the specific coating.

Due to the low surface energy, the adhesive bond between the surface

Fig. 2: Acorn barnacles. Photo courtesy of Mo Riza, licensed under CC 2.0 Generic.

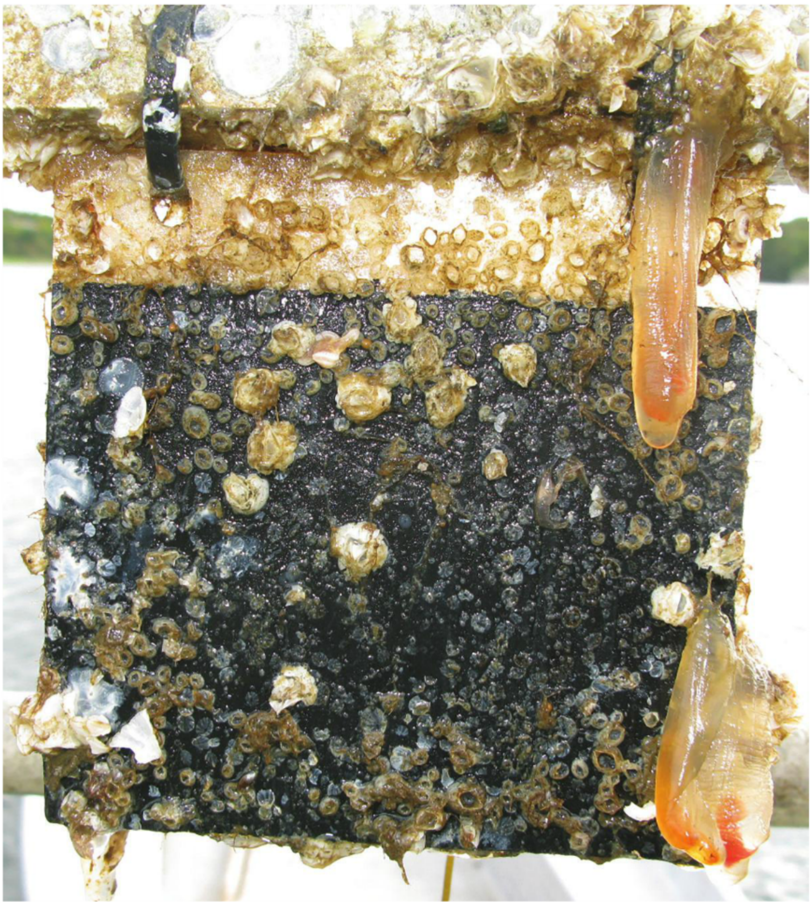

Fig. 3: Shown is a panel attached to a ship's hull on the Swedish west coast. Coated without a biocide (during the short time that copper was banned in the Baltic region), the hull exhibits significantly more fouling than Figure 4. Photo courtesy of I-Tech.

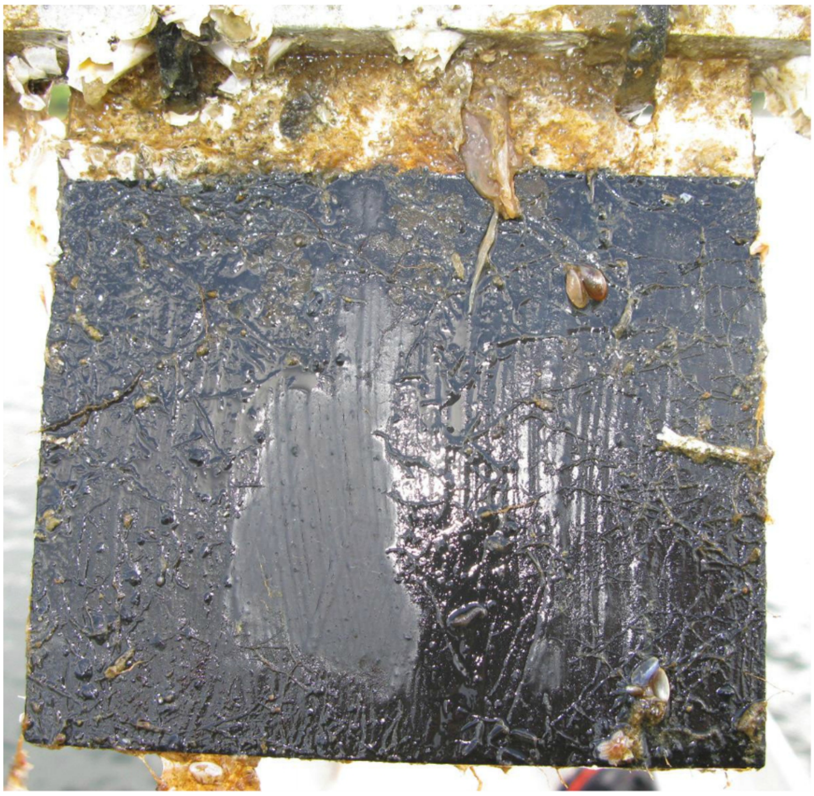

Fig. 4: Shown is a panel attached to a ship's hull, coated with antifouling paint containing medetomidine biocide, after two years of exposure on the Swedish west coast. Photo courtesy of I-Tech.

and fouling organisms is weak and can be easily broken by either the weight of the organism itself (mussels and barnacles) or by the force of the water flowing past.

The technology used today for the majority of foul-release systems is based on silicone elastomers — polydimethylsiloxane (PDMS). These polymers have low surface tension, a low modulus of elasticity and a low micro roughness — the properties needed for easy self-cleaning. While most traditional silicone-based coatings have excellent foul-release properties at relatively high speeds and on vessels with high activity, they do not inhibit fouling while the vessels are idle (when slime tends to build up). This slime fouling is difficult to remove even at high vessel speeds due to its low build.

A second non-biocidal foul-release technology is based on fluoropolymer chemistry, which is said to have improved performance compared to silicone-based systems. These coatings claim benefits such as resistance to mechanical damage, suitable foul-release properties and greater efficiency at lower vessel operating speeds.

The third biocide-free technology takes a completely different approach to fouling control: surface-treated coatings. As opposed to the "soft" coatings described above, this is a "hard" coating. With this philosophy, the so-called surface-treated coatings are subjected to an in-water "conditioning" which is believed to improve the surface characteristics and also remove fouling in the early stages of settlement. The only system using this technology is a proprietary coating based on a vinyl-ester resin with a high concentration of embedded glass flakes. The resultant coating has very low VOC content and is typically applied in two coats of 500 um (.02 inch) each. The presence of the glass flakes produces an extremely durable coating, well-suited for repeated in-water cleaning. The initial conditioning of the surface results in a smooth exterior which fouling organisms have difficulty adhering to.

In this age of environmental and ecological legislation, nontoxic or biocide-free systems are becoming the norm, and a good deal of research is going into alternative systems, much of it looking to nature for answers. For example, we have seen fibrous coatings where polymer fibers are incorporated into the coating so that they protrude out from the surface. This was intended to obscure the actual surface and deter organisms from settling. Researchers also studied sharks and observed that they are selectively foul-free compared to whales, which are prone to barnacle fouling. This lead to developing a coating based on the "sharkskin" effect.

Many alterative materials, both inorganic and organic, have been screened for biocidal activity or fouling control, but exploitation of promising materials can conflict with the Biocidal Products Directive (BPD), a European directive regulating biocidal products and active substances, which required extensive and costly testing before a coating could be put on the market. This has been a barrier to further development, but a new "intelligent" biocide which is particularly effective at preventing barnacle settlement and growth has now been authorized for use.

CHEMISTRY

The biocide — generic name medetomidine — is the result of broad

COMPARING HULL COATINGS: "APPLES TO APPLES"

Biofouling of a ship's hull can significantly affect drag and therefore, the efficiency of a particular hull coating at preventing fouling from settling on the hull is important to ship operators, as this can dramatically affect the operating costs.

Many ship owners will have their own evidence of coating performance based on past experience with similar vessels in their fleets. Obviously, the state of the fouling on the hull can be monitored when the vessel is in port, and data on the ship's performance over time can be obtained from the ship itself. Normally, one set of readings is taken per day (noon data) but there are also several proprietary logging systems which constantly monitor a vessel's performance and send the information back to the owner. There are also several software systems available that can take the data and roughness calculations and predict performance, aiding in coating selection. However, all vessels are different and all hull coatings are different and cannot easily be compared with one another. In addition, there are many variables that can affect a vessel's performance that cannot be predicted, such as weather conditions and differences in fouling potential.

All the major marine coating manufacturers collect historical data on their products, which they use to calculate their effectiveness against fouling in different operating scenarios and thus make claims about potential fuel savings (and hence, reduced operating costs). However, they all use different criteria to determine these savings.

This problem has been known for some time and the industry has been working through the International Organization for Standardization (ISO) on a more transparent method for measuring changes in performance. Because changes in the ship's propeller due to corrosion or other means can also markedly affect power output and therefore fuel use, these factors have to be considered as well. The result is ISO 19030, "Measurement of changes in hull and propeller performance." Part 1: General principles and Part 2: Default model, have been issued as discussion documents and are expected to be published next year, with Part 3: Alternative methods, to follow.

Hopefully, adherence to this independent standard will produce meaningful comparisons between coating selection and fuel savings.

research on the development of environmentally sound marine paints, and was conducted in a Swedish government-funded, multi-year research project. Several reputed biocides were studied, but medetomidine stood out from the others when researchers discovered that it affected the behavior of barnacle larvae, preventing them from settling on surfaces treated with the substance. Its effect was particularly noteworthy, because it was identified at nanomolar concentration levels (~0.1% w/w). Further development refined the product into a verified, ecologically friendly marine biocide for use in antifouling coatings for ship hulls.

How Does it Work?

Existing knowledge of the biology behind barnacle behavior was one of the resources used to identify medetomidine — an analgesic used in veterinary medicine — as an antifouling substance. Unlike toxic biocides, this substance is used to stimulate a specific protein on the cell surface, causing the barnacle larva to start kicking. Unable to attach itself to a surface, it swims away. Because the effect is reversible, the larva will regain its normal behavior when distanced from the painted surface.

According to the company developing this compound, it is effective at very low concentrations due to its high degree of specificity — by being a molecule that modulates a key event in the barnacle life cycle. Due to the low concentration needed, its use does not compromise the coating's chemical structure, color or the effect of co-biocides in the formulation.

The effectiveness of medetomidine against barnacle growth has been demonstrated by panel tests. Figures 3 and 4 (pp. 66, 68) shows panel tests after two years in static condition on the Swedish west coast. Binding technologies for medetomidine have also been developed, such that the active substance can be released in a low and constant concentration from the paint formulation over long periods of time, ensuring a long service life for the coating. These patented technologies include both metallic and organic binding, carrier, and release systems.

CONCLUSION

According to the developer, Medetomidine is up to 300 times more effective by weight than cuprous oxide (copper) for preventing barnacle attachment, and requires that paint contain only a few grams per liter to work efficiently, as opposed to toxic biocides which are effective only when used in high concentrations. *JPCL*

Close Encounters of the Third "Crude-Oil" Kind

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International Paint LLC

Images courtesy of the authors unless otherwise noted.

Steven Spielberg's spectacular film "Close Encounters of the Third Kind" filled us with a sense of wonder as mankind sought to interact with alien species from outer space. In the present work an altogether different sense of wonder filled the authors in the inner-space realm of chemistry and coatings with our own close encounters of the third "crude oil kind."

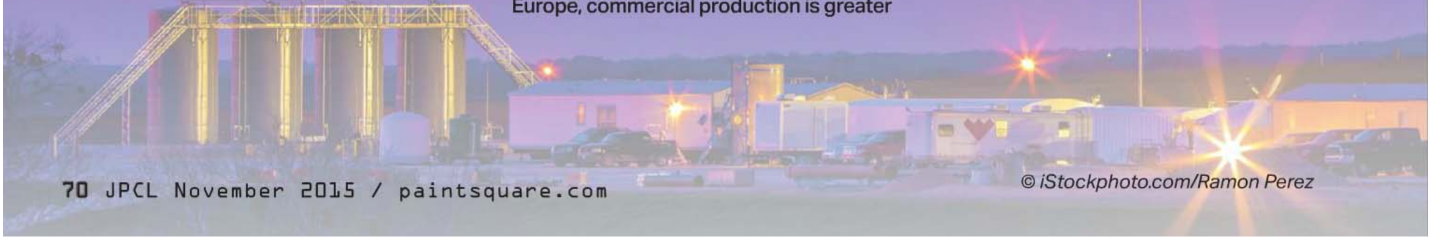
Shale oil is more appropriately known as tight oil, oil that has been known for decades to be locked in shale and other rocks[1]. Today, in conjunction with horizontal drilling, hydraulic fracturing, or "fracking" as it is better known, is used in an extraction process whereby fluids that consist of water, chemicals and sand are injected under high pressure into underground shale rock formation (Fig. 1, p. 72). The subsequent fractures in the fine-grained sedimentary shale rocks are propped open by the sand, thereby facilitating the release and recovery of oil and gas from the shale formations[2].

The production of recoverable shale gas and shale oil from fracking has revolutionized the North American energy sector [3]. According to one source in 2014, "…the shale revolution, the emergence of large amounts of gas, oil coming out of tight rock and the oil sands, North America is the hottest place in the oil worldwide business today…"[4]. In 2013 the top three oil producers in the world (in descending order of rankings) were reported to be Saudi Arabia, North America and Russia. In 2014 the top three producers were North America, Saudi Arabia and Russia[5]. Shale oil production in the U.S. has increased from 5 MMbbl/d in 2008 to greater than 7.4 MMbbl/d in 2013[6]. Unfortunately, however, the sharp decline in oil prices in 2015 has had a marked impact in slowing down oil production. As attractive as shale oil and shale gas are in North America, China is only in the relatively early stages of its commercialization of shale products, while Europe has been somewhat reticent to even start production of its shale reserves due largely to environmental concerns associated with hydrocarbon contamination of groundwater and surface water.

The extent of progress in the production of shale products in the U.S. is demonstrated in the levels of shale gas extracted from the estimated 20 trillion cubic meters of total recoverable shale gas reserves. It has been reported that in the U.S., China and Europe, commercial production is greater than 200 billion cubic meters, 200 million cubic meters, and zero cubic meters, respectively (Fig. 2, p. 72). While research and development rightly continues on renewable energy sources such as solar and wind energy, an overarching global theme is that extractive (non-renewable) sources of oil, gas and coal remain the primary energy sources, as shown in Figure 3 (p. 73)[3].

Risk reduction is crucially important with respect to workers, communities and the environment when it comes to the safe handling, storage and transportation of shale products. Whether the latter are transported by pipeline or railcar, carbon steel should be properly protected by judiciously selected linings. In this way, owners will be afforded long-term corrosion protection and structural integrity of their assets, and oil spills into the environment due to corrosion should be prevented[7].

Lamentably, industrial accidents do happen from time to time, even when structural integrity loss due to corrosion is not the culprit. For instance, in 2008 there were two major derailments of railcars carrying shale oil products — the first in Quebec, Canada, and the second in Alabama[7]. Spills from ruptured pipelines have also occurred. Irrespective of the cause of the accident, it is critically important to



ensure that the carbon steel is protected by high-performance, thermal, water and chemically resistant linings.

In the oil and gas industry, the chemical environment in conventional crude, unconventional crude and shale crude service can be very demanding depending upon whether one is dealing with storage tanks, pipes or vessels such as treaters and separators.

With respect to tanks, aggressive service conditions can include saline solutions, aqueous bacterial sludges such as sulfur-reducing bacteria, oil/water emulsions, water/oil emulsions, sediments, soluble sulfur compounds, low pH environments such as sulfuric acid, high-pressure steam clean-outs and abrasion caused during retrofits.

Vessels and pipes can experience aggressive service conditions as well, such as high temperatures, low-to-high pressures, oil/water emulsions, water/oil emulsions, corrosive gasses including hydrogen sulfide (H_2S) and carbon dioxide (CO_2), high-pressure steam clean-outs and abrasion during retrofits.

Clearly, there are numerous factors that must be carefully assessed before pre-qualifying a lining for a tank, vessel or pipe in the oil patch. If an asset owner chose not to line storage tanks, it would not be surprising if the tanks corroded in a few months and had to be discarded. It has been reported that over 90 percent of the tanks in over 1,500 shale oil-production sites have experienced significant corrosion in the lower 20 centimeters of the tanks[8]. Because of the variety of composition of shale crude oils, it is arguably best to protect the steel tank interiors, vessels and pipes with the highest performing lining systems.

Table 1 (p. 73) shows that a typical Bakken shale oil is paraffinic and contains a high level of unsaturated hydrocarbons and aromatic compounds. Similar findings have been reported elsewhere in a study comparing Jordanian shale oil and some refined petroleum products[9].

Table 2 (p. 73) shows that typical shale oil also contains several heavy metals and high sulfur content. Crude oils are generally classified as sweet or sour when they respectively contain less than, or greater than 0.5 percent sulfur.

Shale Oil Investigated

The shale oil used in the present work had an American Petroleum Institute (API) Gravity of approximately 39.1 degrees. It was obtained from a producer in the Bakken shale play having been through a separator. The water content of the shale oil was approximately 0.06 percent and it has a total acid number (TAN) value of 0.95. The higher the API number, the lighter the oil and the higher the TAN value, the higher the corrosive nature of that oil.

In earlier work, the authors investigated the high-temperature performance of nine polycyclamine-cured epoxy linings where conventional crudes were used as the hydrocarbon phase in autoclave tests, either sour crude (AP1 21 degrees; TAN 0.12) or sweet crude (AP1 21 degrees; TAN 0.94)[10]. Both these crude oils were derived from the steam assisted gravity drainage (SAGD) process in the Alberta oil patch in Canada.

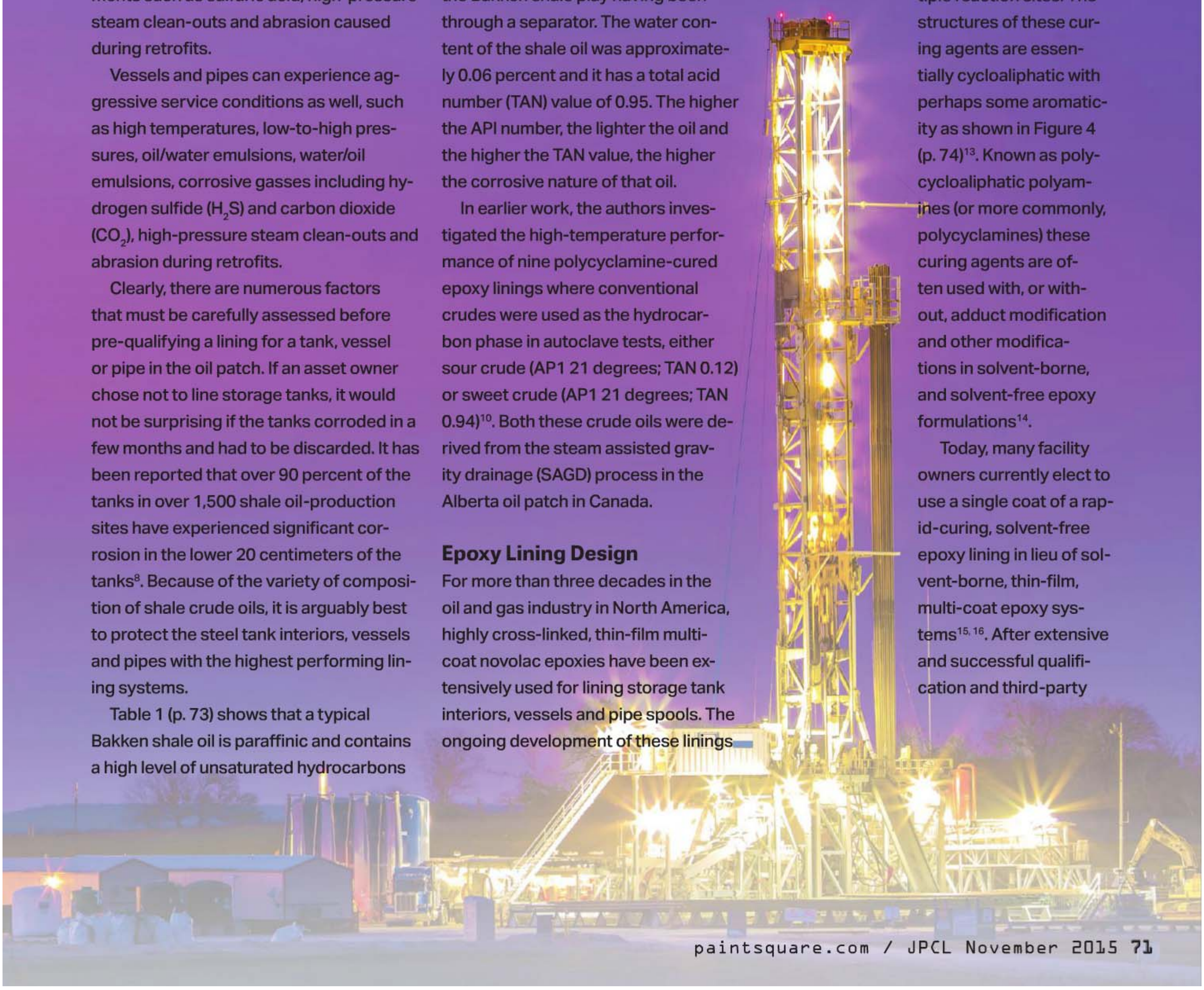
Epoxy Lining Design

For more than three decades in the oil and gas industry in North America, highly cross-linked, thin-film multi-coat novolac epoxies have been extensively used for lining storage tank interiors, vessels and pipe spools. The ongoing development of these linings in terms of hot water resistance, chemical resistance and an ability to "breathe," in order to withstand explosive decompression, is a testament to their proven performance in harsh oilfield conditions.

In terms of the thermal and chemical resistance of epoxy linings, while the epoxy resin structure, reactivity and chemical properties are important (the three resin options being Bis A, Bis F or novolac) it is the curing agent that is the primary determinant of epoxy lining performance[11,12].

Due in part to toxicological and regulatory imposition, curing agents have evolved in the oil patch from aromatic to cycloaliphatic types, the latter possessing multiple reaction sites. The structures of these curing agents are essentially cycloaliphatic with perhaps some aromaticity as shown in Figure 4 (p. 74)[13]. Known as polycycloaliphatic polyamines (or more commonly, polycyclamines) these curing agents are often used with, or without, adduct modification and other modifications in solvent-borne, and solvent-free epoxy formulations[14].

Today, many facility owners currently elect to use a single coat of a rapid-curing, solvent-free epoxy lining in lieu of solvent-borne, thin-film, multi-coat epoxy systems[15,16]. After extensive and successful qualification and third-party



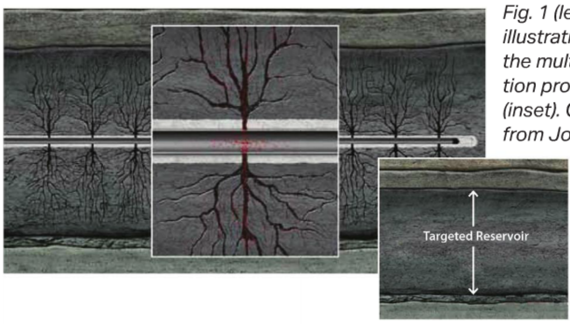
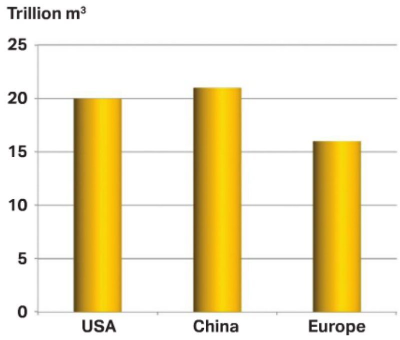


Fig. 1 (left): Schematic diagram illustrating fractures created during the multi-stage hydraulic stimulation process and targeted reservoir (inset). Courtesy of CSUR (Adapted from John Perez Graphics).

Fig. 2 (right): Estimated total recoverable shale gas. Courtesy of Noru Tsalic[3].



independent coatings testing, these polycyclamines have, for the most part, become the curing agents of choice for the past 15 years.

Epoxy Lining Selection

Using Polycyclamine Curing Agents

The accelerated laboratory performance of several epoxy linings was investigated on the basis that the linings selected would offer a range of compositional types with the potential to give good performance at elevated temperatures and pressures, for example 300 F (149 C) and 250 psi, respectively (Table 3, p. 74). The dry film thicknesses (DFT) of some two-coat lining systems were as low as 9-to-11 mils and as high as 30-to-35 mils for some single-coat systems.

Aside from three experimental coatings (B, C and D), all candidate coatings either had track records in tanks, vessels and pipe internal applications in oil and gas service, and one (E) had an extensive service history in railcar applications.

Lining A was a new generation, single-coat epoxy based on a novel polycyclamine curing agent co-reacted with a novolac hybrid epoxy. Attributes of this 96 percent (+/-2) solids by volume (SBV) lining included ease of application by single-leg spray equipment, long pot life (> 1 hour) compared to most other solvent free high build epoxies, rapid cure in a single-coat system of 16-30 mils DFT, no amine blush, and the ability to cure as low as 40 F (5 C).

Lining B and Lining C were respectively ambient-cured and post-cured versions of an experimental epoxy lining based on novolac epoxy technology and a relatively new curing agent technology. The latter had received proprietary modifications.

Lining D was an alternative, and experimental, post-cured version of Lining A.

Linings B, C and D were applied in single-coat applications at about 30-to-35 mils DFT. Each lining cures as low as 50 F (10 C).

Lining E is in widespread use as a single-coat, thick-film lining for frac tanks containing dilute solutions of hydrochloric acid, and railcar interiors carrying shale oil and other types of crude oil, up to temperatures as high as 200 F (93 C). It was the only modified amine-cured phenolic epoxy in this study and was included in the 300 F (149 C) testing given its real-world success in shale oil immersion at 200 F (93 C). As with Lining A, Lining E is normally applied at approximately 12-to-20 mils DFT and for test purposes was kept at the lower DFT of the range.

With significant track records in the oil patch (more than 40 million square feet), the novolac epoxies (Linings F1, F2 and G) are two-coat systems. Lining F1 Blue has a dense and highly cross-linked structure, Lining F2 Gray is a breathable version of Lining F1 Blue, and Lining G is also a breathable epoxy. These linings are solvent-borne, possess a compact three-dimensional structure and have a proven track record demonstrating outstanding water, oil and chemical resistance.

RAILCAR LINED WITH COATING E

During the past three years, a single-coat system of a solvent-free, high-build, modified amine-cured phenolic epoxy was applied at 12-to-18 mils DFT to several hundred railcar interiors used to transport shale oil.

The specification called for an SSPC-SP 10/NACE No. 2, "Near White Blast Cleaning" blast and a sharp angular profile of 2-to-3 mils. A mixture of steel shot and grit was used as the abrasive media. Spray application of the coating system was accomplished using plural spray equipment.

The impetus for the single-coat system was essentially labor savings and low VOC emissions. The labor savings achieved with the fast turnaround, single-coat system was judged to save the fabricator considerable time. The internal lining was deemed to be hard dry in four hours at ambient temperature or hard dry in two hours if vented for one hour and post cured by baking at 150 F (71 C) for another hour.

This project was completed on schedule and all parties were pleased.

One year later the interior linings of two cars were inspected. The owner, railcar fabricator and linings supplier were satisfied. There were no indications that the lining material was wearing or failing.

Table 1: Hydrocarbon Analysis of a Typical Shale Oil

Group Type	Total (Mass %)	Total (Vol %)	Total (Mol %)
Paraffins	9.1233	11.5504	9.5779
I-Paraffins	8.2206	9.9089	7.3923
Olefins	0.1335	0.1607	0.1210
Napthenes	8.4635	9.0463	7.9129
Aromatics	6.7377	6.3819	6.2242
Total C 14 +	0.0000	0.0000	0.0000
Total Unknowns	0.0910	0.1069	0.0689

Table 2: Sulfur, Metals and Salt Analysis of a Typical Shale Oil

Constituent	Result	Units
Sulfur (S)	0.52	Wt %
H_2S as S	3	mg/kg
Mercaptan as S	21	mg/kg
Salts	10.6	1b/1,000bbl
Vanadium	0.1	mg/kg
Nickel	0.98	mg/kg
Iron	155	mg/kg

Historically, Lining F1 blue is used for immersion temperatures in sour produced oil and gas up to 250 F (121 C) and at pressures up to 1,000 psi. In contrast, Lining F2 Gray and Lining G are used at temperatures up to 350 F (176 C) in 5 percent H_2S, 5 percent CO_2 and at 200 psi or, alternatively, at temperatures up to 300 F (149 C) in 5 percent H_2S, 5 percent CO_2 Lining F2 Gray and Lining G are also used when higher pressures are encountered, such as 1,000-to-3,000 psi and where there is a risk of explosive decompression (rapid emergency depressurization).

Lining H was a novolac epoxy that to date has not been used extensively in the North American oil patch.

Testing

Lining Application on Steel Panels

Carbon steel panels measuring 15.0-by-3.8-by-0.32 centimeters (6-by-1.5-by-0.125 inches) were abrasive-blasted to SSPC-SP 5/NACE No. 1, "White Metal Blast Cleaning" standard to obtain a sharp angular profile in the range of 2.5-to-4 mils[17]. Each lining was spray-applied in either shop or laboratory conditions, according to the coating manufacturer's instructions.

Autoclave Testing

To help determine the suitability of a coating for use as a tank and vessel lining, autoclave testing is often undertaken for 96 hours according to NACE TM0185, "Evaluation of Internal Plastic Coatings for Corrosion Control of Tubular Goods by Autoclave Testing."[18].

In autoclave testing, oil field conditions can be simulated with respect to fluid, temperature and pressure, or alternatively, even more aggressive conditions can be pre-selected compared to those encountered in real-world service (Fig. 5, p. 75).

The autoclave test environment consisted of three phases; a gas phase mixture of 10 percent H_2S, 10 percent CO_2 and 80 percent CH_4, a hydrocarbon phase of shale oil from the Bakken shale play, and an aqueous phase of a 5 percent sodium chloride (NaCl) solution. Under the same test conditions, the authors had recently studied some of the linings using sweet or sour crude as the hydrocarbon phase[10].

Electrochemical Impedance Spectroscopy (EIS)

Given that the barrier properties of organic coatings create a high electrical resistance across the lining thickness, EIS can be used in a very short exposure time to detect subtle or large changes in a lining's electrical behavior and barrier properties.

As the linings age, the pores in the network become saturated with water and organic molecules, and are permeated by small gaseous molecules such as H_2S and CO_2. As a result, low resistance paths are created in the lining and a metal substrate is exposed to a corrosive environment.

With EIS, the low frequency impedance (AC electrical resistance) is related to the permeability of the lining to water, organic and gaseous molecules. A lining that exhibits high impedance (log Z of 10) is indicative of low permeability, minimal penetration of corrosives, excellent barrier

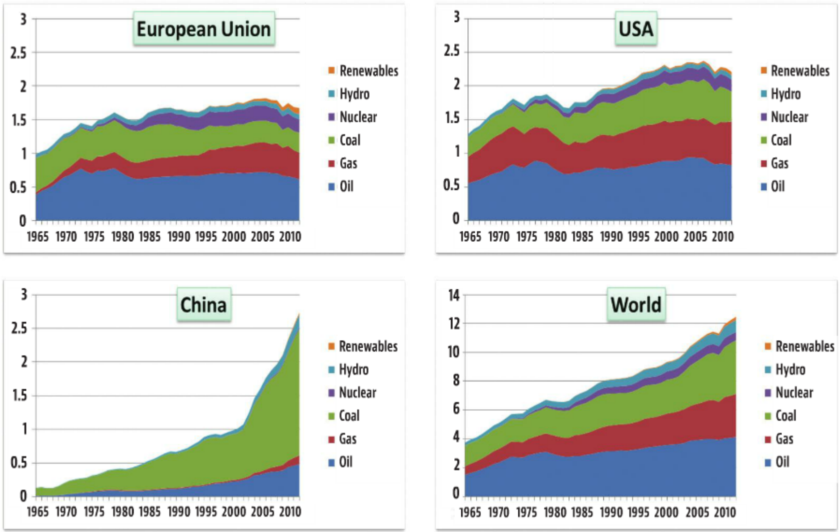


Fig. 3: The source of our primary energy. Courtesy of Noru Tsalic[3].

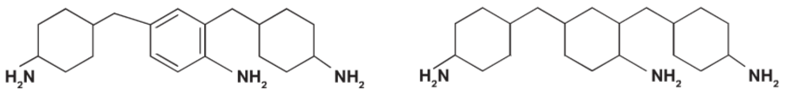


Fig. 4: Structures of typical polycyclamines.

properties and superior corrosion protection of the substrate. In contrast, a lining exhibiting low or marginal impedance (log Z of 6) is indicative of high permeability, poor barrier properties and susceptibility to under-film corrosion.

Visual Inspection and Adhesion

After the coated panels were removed from the autoclave they were evaluated visually for any blistering, cracking or other defects as per ASTM D714, "Standard Test Method for Evaluating Degree of Blistering of Paints"[19] (Fig. 6). The film thickness was measured and the lining adhesion assessed according to the parallel scribe method in NACE TM0185[18]. Two cuts, 1/8-inch apart, were cut through the lining to base metal with an abrasive disc on a Dremel tool. The adhesion of the lining between the scribe marks was evaluated by prying with a utility knife (Fig. 7, p. 76).

Wet adhesion was evaluated within one hour after the panels were removed from the immersion test. Two weeks after the panels were removed from the autoclave immersion test, the dry adhesion was also evaluated using the parallel scribe method. The adhesion was rated using the following scale.

Rating	Description
A	No change/no disbondment
B	Slight Change of Adhesion (>50% still attached)
C	Moderate Loss of Adhesion (<50% still attached)
D	Severe loss of adhesion
E	Disbondment

In addition, for control panels and areas where test panels were subjected to the aqueous phase in the autoclave, the adhesion of each lining was measured according to ASTM D4541, "Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers"[20]. In this test, an aluminum dolly was bonded to the lining film and the applied force required to remove the dolly was measured. Dry adhesion measurements were obtained on panels two weeks after the panels had been removed from the autoclave.

Discussion

The types of curing agents and resins in an epoxy lining predominantly influence hydrolytic, thermal and chemical resistance. The linings used in the present study were either solvented or essentially solvent-free. A common denominator was that each formulation (except Lining E) used multi-functional polycyclamine curing agents and high functionality epoxy phenolic or epoxy novolac resins with functionalities of about 2.1-to-2.8.

It is known that when different epoxy resins and curing agents are mixed in certain proportions they will yield cured epoxy coatings with cross-link densities that reflect the structure, type of reactants and stoichiometry. Cross-link density is envisaged as the distance between the cross-links per unit of length. A high

Table 3: Autoclave – EIS Test Candidate Linings

Lining	Lining Description	Number of Coats	DFT Range mils
A	Solvent-free, HB polycyclamine-cured Novolac Hybrid epoxy	1	17-18
B	Solvent-free, Modified, HB polycyclamine-cured Novolac Hybrid epoxy (ambient cured)	1	31-34
C	Solvent-free, Modified, HB polycyclamine-cured Novolac Hybrid epoxy (post cured)	1	30-31
D	Alternative to A: Solvent-free, HB polycyclamine-cured Novolac Hybrid epoxy (post cured)	1	33-35
E	Solvent-free, high-build modified amine-cured Phenolic epoxy	1	18-20
F1	Thin-film polycyclamine-cured Novolac epoxy (blue)	2	16-18
F2	Breathable, thin-film polycyclamine-cured Novolac epoxy (gray)	2	12-16
G	Breathable, thin-film polycyclamine-cured Novolac epoxy	2	9-11
H	Thin-film polycyclamine-cured Novolac epoxy	2	16 - 18

Table 4: Post-Autoclave Analysis from Test Program

Lining	DFT mils (av)	Adhesion (Parallel Scribe) Rating				Blistering (ASTM D714)			Impedance Log Z @ 0.1 Hz			
		Pre-test	Water	HC	Gas	Water	HC	Gas	Pre-test	Water	HC	Gas
Conditions:		Test temperature 300° F/149° C, pressure 250 psi Gas phase: 10% H_2S, 10% CO_2, 80% CH_4 for 96 hrs Hydrocarbon (HC) phase: Shale Oil, Water phase: 5% NaCl in distilled water										
A	17.8	A	A	A	B	None	None	None	12.23	11.70	11.73	11.75
B	32.5	D	C	D	D	None	None	None	11.56	11.68	11.68	11.71
C	31.0	B	C	D	D	None	None	None	11.52	11.66	11.66	11.81
D	33.9	F	E	E	E	None	None	None	11.55	11.64	11.70	11.75
E	20.9	A	E	E	E	None	None	None	11.63	11.79	11.81	11.80
F	17.3	A	E	E	E	#6M	None	None	11.65	ND	10.77	10.87
F2	13.5	A	E	E	B	#2M	None	None	11.70	ND	11.78	11.75
G	10.1	A	C	C	C	None	None	None	11.77	11.64	11.59	11.64
H	17.0	A	E	C	A	#2 MD to #4D	None	None	11.73	ND	11.59	11.64

DFTs were measured for each lining and each phase

Reported DFT average of each panel

HC = hydrocarbon W = water

ND = Not Done

cross-link density will yield a high chemical resistance and lower flexibility. Lower cross-link density linings, conversely, yield lower chemical resistance and greater flexibility. In this work candidate linings were chosen that would have high cross-link densities and an anticipated high level of chemical resistance for the severe test conditions in the autoclave.

If a lining blistered, cracked or flaked in any of the three phases during the autoclave test, it was deemed to have failed. Adhesion ratings of the linings were considered of lower importance than the presence, or absence, of film blistering.

Linings may provide sufficient adhesion and sub-film corrosion resistance even when water has permeated the film and reached the lining-metal interface[21]. All the linings were ranked on the basis of blistering and adhesion ratings.

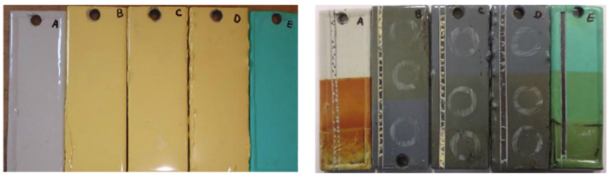


Fig. 5: Appearance of autoclave test panels of Linings A to E, pre-test (left) and post-test (right).

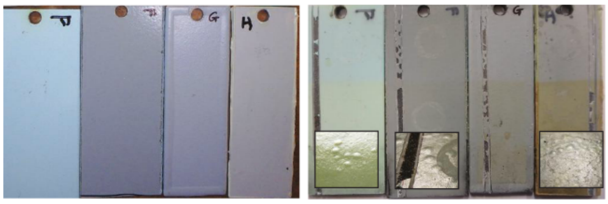


Fig. 6: Appearance of autoclave test panels of Linings F through H, pre-test (left) and post-test (right).The blistering in the acqueous phase is magnified for clarity.

Inspection of Table 4 and Table 5 (p. 76) revealed the following key highlights.

- None of the single-coat, solvent-free epoxies (Linings A through E) blistered during the test conditions.
- Lining G was the only multi-coat, solvent-borne epoxy that did not blister in the water phase. Interestingly, Lining G was approximately half the thickness of Lining A and Lining E, and one-third the thickness of Linings B, C and D.
- There was no correlation between the adhesion ratings derived from the parallel scribe method and adhesion results

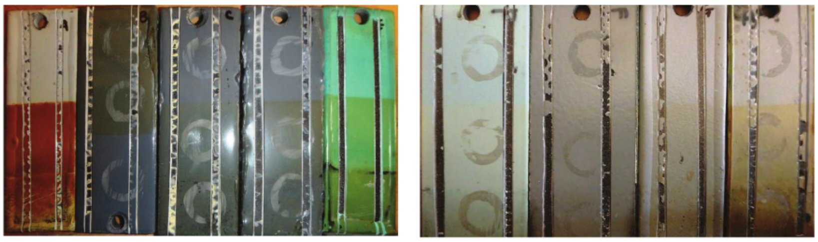


Fig. 7: Appearance of autoclave test panels, parallel scribe post-test adhesion analysis, Linings A through H (left to right). Scribe at post-test after 1 hr (left). Scribe at post test after two weeks (right).

Table 5: Post-Autoclave Analysis from Test Program

Lining	DFT mils (av)	Adhesion (Parallel Scribe) Rating (after 1 hour)				Adhesion (Parallel Scribe) Rating (after 2 weeks)			Adhesion (ASTM D 4541) PSI (after 2 weeks)			
		Pre-test	Water	HC	Gas	Water	HC	Gas	Pre-test	Water	HC	Gas
		Test temperature 300°F/149°C, pressure 250 psi Gas phase: 10% H_2S, 10% CO_2, 80% CH_4 for 96 hrs Hydrocarbon (HC) phase: Shale Oil, Water phase: 5% NaCl in distilled water										
A	17.8	A	A	A	B	A	A	B	577	907	ND	ND
B	32.5	D	C	D	D	A	A	A	>3000	2622	ND	ND
C	31.0	B	C	D	D	A	B	A	2861	2855	ND	ND
D	33.9	E	E	E	E	E	E	E	3000	2595	ND	ND
E	20.9	A	E	E	E	E	E	E	1022	893	ND	ND
F1	17.3	A	E	E	E	C	E	E	1160	613	ND	ND
F2	13.5	A	E	E	B	C	E	E	1363	545	ND	ND
G	10.1	A	C	C	C	E	E	E	731	495	ND	ND
H	17.0	A	E	C	A	B	D	E	892	568	ND	ND

ND = Not Done

obtained from ASTM D 4541 dolly pulls, nor was any expected.

- The experimental Linings B, C, and D had the highest adhesion strengths measured from the dolly pulls (> 2,500 psi).
- Lining A was the only single coat of solvent-free epoxy with apparently low adhesion strengths (glue failed) compared to the other solvent-free epoxy linings.
- For Lining A, the adhesion (wet) measured one hour after the autoclave test in the parallel scribe test was found to be virtually the same as the adhesion (dry) after two weeks.
- For Lining B and Lining C, the adhesion (wet) measured one hour after the autoclave test in the parallel scribe test was found to recover with time. This is evidenced in the adhesion (dry) results after two weeks.

Lining A tested best overall in the hot aqueous, gaseous and shale oil media and had the best parallel scribe adhesion test results. Curiously, in the dolly pull test using ASTM D4541, Lining A appeared to be the poorest amongst the solvent-free epoxies where glue failure occurred on three consecutive dolly pulls. It is speculated that the small amount of a fluorinated compound (uniformly dispersed) in this lining caused the apparent lower adhesion results compared to the other solvent-free epoxy linings. Fluorine atoms would cause a low surface energy making it difficult for adhesion of the glue. In the parallel scribe test, however, a prying action would be at the base of the lining and the fluorinated compound would not be a factor.

Under the same autoclave conditions used in this study, Lining A recently performed best in a test where the authors used sweet and sour crude oils instead of shale oil[10].

The ambient-cured, single-coat modified polycyclamine cured novolac epoxy Lining B, and post-cured version Lining C, originally displayed poor parallel scribe adhesion results indicating poor wet adhesion one hour after having been withdrawn from the autoclave. However, two weeks later the parallel scribe ratings on these linings were exceptional. Not only had the adhesion recovered but it had become markedly better than that of the untested control panel for Lining B (exhibiting a D-to-A rating increase) and marginally better than that of the untested control panel for Lining C (exhibiting a B-to-A rating increase). These performance changes were not observed using the ASTM D4541 adhesion testing where the results were good with tensile pulls measured in excess of 2,500 psi.

Lining D was a post-cured, single-coat and higher-DFT alternative formulation of the ambient-cured Lining A. From the evidence of the parallel scribe ratings, Lining D failed the test whereas Lining A passed it.

Lining E, similar to Lining A, was applied at about 18-to-20 mils DFT in a single coat. The wet adhesion of this lining was poor with an E rating and the adhesion did not recover with time. In contrast, however, the ASTM D4541 test results for Lining E were good and approximately 1,000 psi. The proven success of Lining E as a railcar lining for shale oil transportation, where the adhesion of coatings is severely tested with the flexing of railcars, suggests more credence should be given to ASTM D4541 adhesion test data than to parallel scribe ratings.

In the case of the solvent-borne linings, Linings F1, F2, G and H, only Lining G performed well under the aggressive conditions tried.

Lining F1 is fit for oil and gas service in tank, vessels and pipe spools up to 250 F (121 C) and has a proven track record of hydrolytic, thermal and chemical resistance up to this upper temperature threshold and up to 1,000 psi. As already known from field work and autoclave — EIS studies using sweet crude and sour crude, Lining F1 was not expected to withstand 300 F (149 C). However, it was selected in the present work for comparison against other linings which were anticipated to perform well in the temperature range of 300F to 350 F (149 C to 177 C).

The solvent-borne Lining F2 and Lining G use the same epoxy novolac resin and polycyclamine curing agent. Both are designed for use where explosive decompression may occur. These linings have a higher permeability than Lining F1, which allows them to breathe so that water and gases penetrate and release from the lining more rapidly than do with Lining F1. It is noteworthy that Lining G, at approximately 10 mils DFT film, performed well in the autoclave test even when it had half the thickness of the other high performers, namely Lining A and Lining E.

All of the linings had outstanding pre-test and post-test log Z impedance values (log Z > 11) except for Lining F1 where the log Z dropped to greater than 10 post-test (also excellent). There was essentially no discrimination of performance between the linings tested with the exception of Lining F (blue), a solvent-borne, novolac epoxy that is used for oil patch services up to 250 F (121 C) and not the 300 F (149 C) tested here.

Conclusions

Lining A is a commercially available, single-leg, spray-applied, single-coat, thick-film, solvent-free epoxy novolac coating with a polycyclamine curing agent. It exhibited the best performance in the aggressive autoclave test conditions of 300 F (149 C), 250 psi, 10 percent H_2S and 10 percent CO_2, and in the "third crude oil kind," a shale oil hydrocarbon phase.

Linings B, C and D were experimental thick-film, single-coat, solvent-free, polycyclamine-cured epoxy novolac coatings. They performed well in the autoclave study but not as well as Lining A.

The ambient-cure version of Lining B, and its post-cure version, Lining C, performed almost identically. Both were superior in performance to Lining D, which was a post-cured alternative to Lining A.

Lining E, a thick-film, single-coat, solvent-free, modified amine-cured phenolic epoxy used to transport shale oil in railcars, also performed well in the markedly more aggressive autoclave test conditions compared to those required for its railcar service.

Among the thin-film, multi-coat, solvent-borne coatings (Linings F1, F2, G and H), only Lining G performed quite well. However, its performance is noteworthy given that the Lining G system was applied in two coats of 5 mils DFT per coat compared to a single coat of 20 mils DFT for Lining A.

The judicious selection of a lining system is critically important to complete a given project and provide an asset owner with the best net return on his or her investment. Ingenuity in the design of linings by coating formulators is very challenging. When VOC regulations become increasingly more stringent the coating formulator's contribution is pivotal.

Against this backdrop, success in a lining project depends on many other factors. It cannot be overemphasized, for example, that the requirement for a well-written specification, proper surface preparation in accordance with the governing specification, onsite surveillance from third-party inspection, and superior application from a pre-qualified contractor are also of critical importance. Ultimately, all of these factors are required to achieve lining success.

About the Authors

Mike O'Donoghue is the Director of Engineering and Technical Services for International Paint LLC. He has 33 years of experience in the protective coatings industry.

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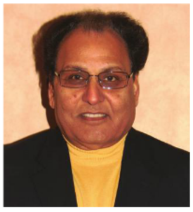
Mike O'Donoghue



Vijay Datta

Acknowledgements

The authors wish to express sincere appreciation to Noru Tsalic, of AMI Consulting, for providing insightful information on the shale oil revolution during the course of these studies. In addition, the authors wish to acknowledge Edward Shanks and Paul Gagnon of International Paint for their considerable assistance in this work.

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AWARDS AND SPECIAL EVENTS AT SSPC 2016

SSPC President Jim King (2014-2015, second from left) and Brad Rossetto of The Sherwin-Williams Company (third from left) prepare to cut the ribbon to the SSPC 2015 exhibit hall as SSPC Board members look on. Photos courtesy of SSPC unless otherwise specified.

A variety of special events, including SSPC's Annual Business Meeting and Awards Luncheon, will take place during SSPC 2016 featuring GreenCOAT at the Henry B. Gonzalez Convention Center in San Antonio, Texas from January 18 to 21, 2016.

Complete information about the conference, including the technical program, workshops, training and certification programs and exhibition, is available at www.sspc2016.com and will be published in the SSPC 2016 Advance Program section of the December 2015 *JPCL*.

ANNUAL BUSINESS MEETING AND AWARDS LUNCHEON

MONDAY, JAN .18, 11:00 A.M. TO 1:00 P.M.

Join SSPC President Skip Vernon, Executive Director Bill Worms, the Board of Governors and your peers to hear SSPC's annual report and honor the 2015 award recipients. The awards to be presented this year include the SSPC Honorary Life Member, the John D. Keane Award of Merit, the SSPC Coatings Education Award, the SSPC Technical

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Achievement Award, the Women in Coatings Impact Award, the President's Lecture Series Awards, the SSPC Outstanding Publication Award, the *JPCL* Editors' Awards, the SSPC Outstanding Chapter Awards, and the 10th annual SSPC Structure Awards.

SSPC HONORARY LIFE MEMBER

This honor is presented to an individual by the Board of Governors for extraordinary contribution and longterm activity on behalf of SSPC. To become an honorary life member, an individual must be nominated by a Board member and approved by two-thirds of the Board. Only one honorary life membership is awarded each year.

JOHN D. KEANE AWARD OF MERIT

Named for SSPC's executive director from 1957 to 1984, this award acknowledges outstanding leadership and significant contribution to the development of the protective coatings industry and to SSPC.

SSPC COATINGS EDUCATION AWARD

This award is given for significant development and dissemination of education material and technical information relating to protective coatings and their application.

SSPC TECHNICAL ACHIEVEMENT AWARD

This award recognizes outstanding service, leadership and contribution to the SSPC technical committees.

WOMEN IN COATINGS IMPACT AWARD

SSPC's newest award was established at SSPC 2014 to recognize women in the coatings industry whose contributions have created a positive impact on the culture of the industry.

PRESIDENT'S LECTURE SERIES AWARD

This award honors a technical presentation that is handpicked by the SSPC president and chosen for its reflection of the coatings industry and profession. The presentation will be highlighted in the SSPC 2016 onsite guide, and the winner will be recognized at the Awards Luncheon.

SSPC OUTSTANDING PUBLICATION AWARD

This award is given annually to the author(s) of the best technical paper or presentation from the SSPC International Conference and Exhibition or from *JPCL* that scores the highest in the following categories: clarity of expression and organization; originality of content or presentation; importance to the protective coatings industry; and effectiveness of figures or tables.

SSPC selects a panel of judges from SSPC and *JPCL* to vote on the award.

JPCL EDITORS' AWARDS

The same panel of judges selects the recipients of the *JPCL* Editors' Awards, which also recognize excellence in technical writing. Winners are selected from a field of more than 100 eligible papers from SSPC 2015 and from *JPCL* articles published between May 2014 and July 2015. Awards are also based on clarity, originality, significance to the industry and effective use of illustrations.

SSPC OUTSTANDING CHAPTER AWARDS

Each year, SSPC presents awards to the Outstanding North America Chapter and the Outstanding International Chapter. Chapters are evaluated on their overall operation and the creativity and quality of the events held each year.

SSPC STRUCTURE AWARDS

The 10th annual SSPC Structure Awards will honor teams of contractors, designers, end users and other personnel for excellence and expertise demonstrated on industrial

EXHIBITORS AT SSPC 2016

THE FOLLOWING LIST OF COMPANIES PLANNING TO EXHIBIT AT SSPC 2016 IS CURRENT AS OF PRESS TIME. FOR INFORMATION ON EXHIBITING, CONTACT KATE JURIK, SSPC EVENT MANAGER & EXHIBIT SALES SPECIALIST, AT JURIK@SSPC.ORG OR 877-281-7772, EXT. 2211.

ABRASIVES INC.
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AIR SYSTEMS INTERNATIONAL, INC.
AMERAGUARD PROTECTIVE COATINGS
ARID-DRY
ARMEX
ARS RECYCLING SYSTEMS, LLC
ATLANTIC DESIGN INC.
AXXIOM MFG./SCHMIDT ENGINEERED ABRASIVE SYSTEMS
BARTON INTERNATIONAL
BELLEMARE GROUP
BINKS
BLASTPRO MANUFACTURING
BLASTRAC
BON TOOL CO.
BULLARD
CARBOLINE
CESCO / AQUA MISER
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COATINGSPRO MAGAZINE
CSI SERVICES
CUSTOM ABRASIVES
DAMPNEY CO. INC.
DEFELSKO CORPORATION
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DENSO NA
DESCO MANUFACTURING CO., INC.
DETROIT TARP
DEX-O-TEX BY CROSSFIELD PRODUCTS
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DRYAIR BY TRASK-DECROW MACHINERY
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DUSTLESS BLASTING
EAGLE INDUSTRIES
ELCOMETER
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FORRESTER ENVIRONMENTAL SERVICES, INC. (FESI)
GMA GARNET GROUP
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MARCO
MIDSUN SPECIALTY PRODUCTS, INC.
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MONARFLEX BY SIPLAST
MONTI TOOLS INC.
MONTIPOWER, INC.
NACE INTERNATIONAL
NATIONAL EQUIPMENT CORP.
NEXTEC INC./PRETOX
NOVATEK CORP
NOVETAS SOLUTIONS (NEW AGE BLAST MEDIA)
NRI
NU WAY INDUSTRIAL WASTE MANAGEMENT
OLIMAG SAND
OPTA MINERALS, INC.
OXIFREE METAL PROTECTION
P&L METALCRAFTS LLC
PACIFIC DUST COLLECTORS
POLYGON
PPG PROTECTIVE & MARINE COATINGS
RAPID PREP
RAVEN LINING SYSTEMS
RBW ENTERPRISES INC.
RING POWER
RUST-OLEUM
RUSTIBUS INC.
SABRE AUTONOMOUS SOLUTIONS
SAFE SYSTEMS INC.
SAFETY LAMP OF HOUSTON
SAFWAY SERVICES LLC
SAND EXPRESS
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SIMPSON STRONG-TIE
SPIDER
SPONGE-JET, INC.
SULZER MIXPAC USA, INC.
SUNBELT RENTALS INC.
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TESLA NANOCOATINGS
TIOGA AIR HEATERS, LLC
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VAN AIR SYSTEMS
VERSAFLEX INC.
VITRO MINERALS
W ABRASIVES
THE WAREHOUSE RENTALS & SUPPLY
WASSER COATINGS
WESTERN TECHNOLOGY
WIWA LP

and commercial coatings project. Awards to be presented are:

- The William Johnson Award for outstanding achievement demonstrating aesthetic merit in industrial coatings work;
- The E. Crone Knoy Award, recognizing outstanding achievement in commercial coatings work;
- The Charles G. Munger Award for an industrial or commercial project demonstrating longevity of the original coating;
- The George Campbell Award, recognizing the completion of a difficult or complex industrial coatings project; and
- The Military Coatings Award of Excellence for exceptional coatings work performed on U.S. military ships, structures or facilities.

JPCL will feature this year's Structure Awards recipients in a photo essay next spring.

OPENING CELEBRATIONS

WELCOME RECEPTION IN THE SPEAKEASY

MONDAY, JAN. 18, 5:30 TO 7:30 P.M.

Sponsored by Carboline

Back when the bathtub gin was cold and the nights were hot, people really knew how to party. Join your friends, colleagues and peers at our Speakeasy. Just remember to knock three times and whisper the password!

EXHIBIT HALL RECEPTION

TUESDAY, JAN. 19, 5:00 TO 8:00 P.M.

Sponsored by The Sherwin-Williams Company

Don't miss the ribbon cutting at 5:00 and the chance to roam the newly opened exhibit hall. Food, beverages and all of the suppliers you need to see await you.

SSPC 2015 Welcome Party.

MEETINGS AND OTHER EVENTS

YOUNG PROFESSIONALS MEETING

MONDAY, JAN. 18, 4:30 TO 5:30 P.M.

Young industry professionals are invited to gather before the Welcome Reception for an opportunity to discuss how the next generation can impact the industry, learn what career paths are available and seek a leadership role in shaping the future.

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FACILITY OWNERS' BREAKFAST AND PEER FORUM

TUESDAY, JAN. 19, 7:30 TO 10:00 A.M.

Facility owners are invited to join the QP-certified contractors at a complimentary breakfast to thank them for their commitment to quality coating projects. During the breakfast, a panel of peers will present thought-provoking questions to initiate discussion. Facility owners only, please. An RSVP is appreciated.

MEGA RUST MID-YEAR FOLLOW UP

WEDNESDAY, JAN. 20, 8:00 A.M. TO 12:00 NOON

The mid-year follow up to the Mega Rust 2015 Conference is scheduled as part of SSPC 2016 and is designed to continue the discussion on key corrosion issues concerning Navy enterprises, generate questions and talking

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points for potential presenters at Mega Rust 2016, discuss the meeting theme and draft the conference agenda. If you are interested in participating in Mega Rust 2016, please email ASNE at MegaRust@navalengineers.org or contact Mega Rust Chairman Dave Zilber, dzilber@mmm.com.

LUNCH WITH EXHIBITORS
WEDNESDAY, JAN. 20, 11:30 A.M. TO 1:00 P.M.
sponsored by Mega Rust
THURSDAY, JAN. 21, 11:30 A.M. TO 1:00 P.M.
sponsored by *CoatingsPro*
SSPC and sponsors invite you to complimentary lunches in the Exhibit Hall. Tickets will be in your registration packet. You've got to eat, right?

PROTECTIVE COATINGS SPECIALISTS BREAKFAST
THURSDAY, JAN. 21, 7:30 TO 9:30 A.M.
The Protective Coatings Specialist (PCS) certification program identifies and awards recognition to individuals who have in-depth knowledge in the principles and practices of industrial coatings technology. Certification attests to the professional credibility of the coatings practitioner and raises the standards of the protective coatings profession. All PCS certified individuals are invited to this complimentary breakfast. An RSVP is appreciated.

RSVP for any of these special events by contacting Jim Kunkle at kunkle@sspc.org or 412-281-2331 ext. 2210.

CLOSING CELEBRATIONS

EXHIBIT HALL CLOSING BLAST
THURSDAY, JAN. 21, 1:30 TO 3:00 P.M.
One final opportunity for interaction with the exhibitors before the hall closes at 3:00 p.m. Grab a beverage and dessert and get that last bit of vendor information to complete your conference experience.

CLOSING PARTY
THURSDAY, JAN. 21, 7:00 TO 9:00 P.M.
A low-key chance to say good-bye to friends new and old, and prepare for the return to work, full of information, industry news and contacts made during the week.

San Antonio Riverwalk. © iStockphoto.com/DavidSucsy

SPOUSE AND GUEST EVENTS

Two optional events are available for SSPC 2016 attendees' spouses and guests. The costs of these events are not included in the conference registration. Tickets for each are $95 if you register before Nov. 17, $110 if you register between Nov. 17 and Dec. 15, and $125 if you register after Dec. 15.

Register for these events online at the SSPC 2016 website. It is not necessary to register for the conference in order to register for these events.

"RELEASE YOUR INNER ARTIST" TUESDAY, JAN. 19, 1:00 TO 4:00 P.M.,

Marriott Rivercenter

Let your artistic side shine! Pinot's Palette comes to you for a one-of-a-kind, fun and friendly painting class! It has been said that, "Every child is an artist." The folks at Pinot's Palette have found a way to bring that child out in adults — with their relaxed, fun environment and expert guidance from local artists. Not an artist? No big deal! Talented instructors will guide you step-by-step to create your masterpiece. Enjoy snacks and wine as you work and take your canvas with you at the end of class. Your canvas will be sized to travel!

WINERY UNIVERSITY WEDNESDAY, JAN. 20, 1:00 TO 4:00 P.M.,

Dry Comal Creek Vineyards

Visit Dry Comal Creek Vineyards and Winery and learn what all the fancy words and odd codes on wine labels mean. Tour wine labels from Texas to Tasmania and learn enough to be dangerous at your neighborhood winery! Each participant will receive printed materials and taste wines from winemaker Franklin Houser. Located in New Braufels, the Housers have been producing wine since 1998, the same year their tasting room opened.

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Photo courtesy of International WorkBoat Show.

INTERNATIONAL WORKBOAT SHOW DOCKS IN NEW ORLEANS

From December 1 to 3, the Ernest N. Morial Convention Center in New Orleans will host the 2015 International WorkBoat Show and Annual Conference. Presented by *WorkBoat* magazine, this annual gathering of marine and offshore owners, representatives and suppliers is composed of keynote speeches, technical presentations, a career fair and an exhibit hall with more than 1,000 product and service providers. Conference attendees include boat and vessel owners and operators, shipyard personnel and commercial boat builders, marine engineers and architects, equipment manufacturers and distributors, port authorities and port engineers, marine surveyors, military buyers and government officials, oil exploration and production representatives and others.

Complete information on the 2015 WorkBoat Show and Conference can be found at the official conference website, www.workboatshow.com.

CONFERENCE SCHEDULE

The following technical sessions at the 2015 WorkBoat Conference may be of interest to protective coatings professionals in the marine and offshore industries. For a complete schedule, visit the conference website.

TUESDAY, DEC. 1

- "The Internet of Things Comes to the Workboat Industry," by Jaime Tetrault, Caterpillar Marine; 10:45 to 11:30 a.m.
- "Beyond VGP: Choosing the Best EAL for Your Application Needs," by Darren Lesinski, Total Specialties U.S., Inc.; Scott Kovanda, American Chemical Technologies Inc.; Mark Miller, RSC Bio Solutions; and Erica Nemser, Compact Membrane Systems Inc.; 10:45 to 11:30 a.m.
- " When the Bad Thing Happens: Identifying and Minimizing the Risk of Punitive and Criminal Penalties," by Mike Bowman and Jedd Malish, Baldwin Haspel Burke & Mayer LLC; 11:45 a.m. to 12:30 p.m.
- "Subchapter M — The Top Five Things You Need To Know and Do Now," by Ian McVicker, ABS Group; and Kevin Gilheany, Maritime Compliance International; 2:30 to 3:15 p.m.
- "Winds of Change: The Evolution of Crew Transfer Vessels," by Marcia Blount, Blount Boats Inc.; 3:30 to 4:15 p.m.
- "Big Data Meets Vessel Risk Management," by Martin McCluney, Marsh USA, Inc.; 3:30 to 4:15 p.m.

WEDNESDAY, DEC. 2

- "Ballast Water Management Compliance," by Jan Flores, NETSCo., Inc.; and Kevin J. Reynolds, Glosten Associates; 10:45 to 11:30 a.m.
- "EPA Vessel General Permit Compliance of Propulsion Equipment," by Brian Fariello, Propulsion Ship Power; 3:30 to 4:15 p.m.

THURSDAY, DEC. 3

- "Maritime Work Force Career Fair," 10:00 a.m. to 2:00 p.m.
- "Building a Better Workforce," by Melissa Kirsch, Workforce Development Board; Dr. Tina Tinney, Northshore Technical Community College; Jennifer Impastato, Louisiana Workforce Commission; and Camille P. Conaway, Louisiana Association of Business and Industry; 10:30 to 11:15 a.m.
- "Millennials, The Next Generation of Mariners," by Jeff Slesinger, Delphi Maritime; 11:30 a.m. to 12:30 p.m.
- "Hiring Veterans, Todays Heroes are Tomorrows Workforce," by Scottie LeBlanc, Louisiana Workforce Commission; 1:00 to 1:45 p.m.

EXHIBITORS AT WORKBOAT 2015

The following list of exhibitors, with corresponding booth numbers, at WorkBoat 2015 that may be of interest to protective coatings professionals is current as of press time. For a complete list, visit www.workboatshow.com.

American Sprayed Fibers Inc. 4775
Atlas Copco Compressors Inc. 4449
AV-DEC..508
AZZ Galvanizing Services...................3162
BAE Systems Southeast Shipyards...2517
BIC Alliance 3405
Big Top Manufacturing.......................3559
Bullard 529
Bullard Abrasives..................................808
Carboline Company............................1317
Colonna's Shipyard Inc. 2451
Current Inc. 2459
Cygnus Instruments, Inc. 1350
DRYCO...1164
Duraflex, Inc. 4605
Eagle Industries.....................................602
Eureka Chemical Company...............1349
Gulf Coast Paint Mfg. 3462
Hempel (USA) Inc. 3216
Ingersoll-Rand 3401
In-Mar Solutions..................................1127
International Marine and Industrial Applicators, LLC............................3765
International Paint LLC....................... 1841
Jotun Paints Inc. 3309
Klingspor Abrasives..............................715
Lonseal Inc. 1862
Malin International Ship Repair & Drydock 2250
Marine Jet Power Inc..........................4227
Mascoat...4044
Metals USA - Plates & Shapes 2755
NACE International 709
NCP Coatings Inc. 3606
Orion Solutions...................................4162
PPG Protective & Marine Coatings 3101
Ramco Manufacturing 1162
Rustibus 3555
The Sherwin-Williams Co..................2541
Sika Services AG.................................4709
Sponge-Jet Inc. 3707
SSPC: The Society for Protective Coatings..................1155
Vigor Industrial....................................4441
Wheelabrator Group...........................2761
WorkBoat Magazine/ WorkBoat.com 310

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ITW Engineered Polymers
KTA-Tator, Inc.
PPG Protective and Marine Coatings
The Sherwin-Williams Company
Tnemec Company, Inc.

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Chevron Energy and Technology
Chicago Bridge & Iron Company
City Of Virginia Beach
Cives Steel Company, Midwest Division
Colonna's Shipyard, Inc.
Continental Maritime of San Diego
Energy Northwest
Fairhaven Shipyard
GE Power Conversion
Golden Gate Bridge Highway & Transportation District
Grant County Public Utility District
Hirschfeld Industries Bridge
Hyundai Samho Heavy Industries Co., Ltd.
Illinois Dept. of Transportation
Indiana Department of Transportation
Kentucky Transportation Cabinet
Louisiana Department of Transportation & Development
Luminant
Lyon Shipyard, Inc.
Maine Department of Transportation
Marisco Ltd.
Maryland State Highway Administration
Ministry of Transportation Bridge Office
Minnesota Department of Transportation
MODOT Maintenance Operations
Monroe County Water Authority
National Steel & Shipbuilding Co.
NAVFAC EXWC
NAVSEA
Norfolk Naval Shipyard Production Department
North Carolina DOT
North Florida Shipyards, Inc.
Mayport Naval Station
NYC School Construction Authority
Ohio Department of Transportation Central Office
Oklahoma Dept. of Transportation
Pacific Ship Repair & Fabrication, Inc.
Pacific Shipyards International
Pearl Harbor Naval Shipyard & IMF
Pennsylvania Dept. of Transportation Materials & Testing
Port of Seattle - Marine Maintenance
Portsmouth Naval Shipyard Code 250
Puget Sound Naval Shipyard II
Southern Company
SSGC-PASC-NAVSEA
Steel Service Corporation
Sumitomo Heavy Industries - Sasebo Base Office
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446 Painting LLC
A & K Painting Company, Inc.
A & S Industrial Coatings
A&L Industrial Services
A-1 Coatings Co.
A-1 Industrial Maintenance
A. W. Chesterton Company
ABC Applicators, Inc.
ABC Trading Solutions
Aberfoyle Metal Treaters Ltd.
Abrasive Blasting & Coating, Inc.
Abrasive Blasting Service & Supplies Pty Ltd.
Abrasives Inc.
ABS - American Bureau of Shipping
Abu Dhabi Construction Company LLC
Adelphi Inc. DBA G-Force Contracting
ADF Industrial Coating Inc.
Advance Coating Solutions Inc.
Advanced Industrial Services LLC
Advanced Industrial Services, Inc.
Advanced Marine Preservation, LLC
Advanced Polymer Coatings, Ltd.
Advanced Recycling Systems, Inc.
Advantage Steel and Construction LLC.
Aegis Coatings Professional Painting Contractors
AEIS, LLC
Aggreko LLC
Ahern Painting Contractors, Inc.
AIR Systems International
Airco Sandblasting, Inc.
Akzo Nobel International Paint (Suzhou) Co., Ltd.
Al-Jazeera Paints Academy
Alabama Painting, Inc.
Alaron Nuclear Services
Albi Manufacturing
All Quality Painting Inc.
All Set Services LLC.
All-Safe Industrial Services, Inc.
All-Star Cleaning & Preservation
All-States Painting, Inc.
Allan Briteway Electrical Contractors, Inc.
Allied Painters Corporation
Allied Painting Inc.
Allnex USA Inc.
AlpAccess
Alpha Painting and Construction Company, Inc.
ALS Industrial Services
Altamira & CIA, S.C. de C.V.
AM-COAT Painting, Inc.
Ameraguard Protective Coatings
American Industrial Hygiene Assoc.
American Suncraft Construction
American Tank & Vessel, Inc.
American Venture Construction LLC
Amherst Maintenance Inc.
Amstar of Western New York
Anchor Paint Mfg Co
Anderson Hydra Platforms Inc.
Anka Painting Company, Inc.
Anticorrosivos Y Acabados AYA
Apache Industrial Services, LLC.
APBN Inc.
API Distribution
Apollon Painting Company, Inc.
Applewood Painting Co.
Applied Coatings & Linings
Applied Corrosion Technology Co. LLC
Ar-Tech Coating Ltd.
Arena Painting Contractors, Inc. (APC)
Arid Dry by CDIMS
Arizona Coating Applicators, Inc.
Asianway Corrosion Protection Engineering Co., Ltd.
Astron General Contracting Co., Inc.
Athab Qatar Engineering & Contracting Co. WLL
Atlantic Design Inc.
Atlantic Painting Co., Inc.
Atlas Painting & Sheeting Corp.
Atlas Steel Coatings Inc.
Automatic Coating Ltd.
Axxiom Manufacturing Inc.
Babcock Canada Inc.
Barton International
Barton-SteelStar
BASF Corporation
Bayer MaterialScience Trading (Shanghai) Co., Ltd.
Baytown Painting, Inc.
Bazan Painting Company
Bellemare Group
Belzona Polymerics Limited
Best Performance Engineering Company Limited
Best Transformer
Bilton Welding & Manufacturing Ltd.
Black Bear Coatings & Concrete
Blastal Coatings Services, Inc.
Blastco Inc.
Blastech Enterprises, Inc.
Blastrac NA
Blastrite Pty. Ltd.
Blendex Industrial Corporation
BMP Sandblasting & Painting
Bon Tool Co.
Boville Industrial Coatings Inc.
Brace Integrated Systems
Bridges R Us Painting Co., Inc.
Brother's Specialized Coating Systems Ltd.
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Buckman Laboratories, Inc.
Bullard Co.
BYK Additives & Instruments
C & K Johnson Industries, Inc.
C.E. Adkins & Son Inc.
C.W. Beal, Inc.

Cabrillo Enterprises, Inc. DBA-R.W. Little Company
Cactus Coatings Ltd.
Caid Industries Inc.
Caldwell Coatings, LLC
Caldwell Tanks, Inc.
California Engineering Contractors, Inc.
Caligari Gerloff Painting, Inc.
Campbell Consulting Services, Inc.
CanAm Minerals/Kleen Blast Abrasives
Cape Environmental Management Inc.
Capitol Finishes, Inc.
Carabie Corp.
Cardolite Corporation
Career Marine Engineering & Trading
Carneys Point Metal Processing, Inc.
Carolina Coating Solutions and Industrial Services, Inc.
Carolina Painting Company, Inc.
CB Tech Services, Inc.
CCI Industrial Services
CDV Industrial EIRL
Cekra Inc.
Central Sandblasting Company, Inc.
Century Industrial Coatings
Certified Coating Specialists Inc.
CESCO/Aqua Miser
Chariot Robotics
Charter Coating Service (2000) Ltd.
Chicago Area Painting Apprenticeship School
Chlomil, Inc. dba Phoenix Maintenance Coatings
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Church & Dwight Company, Inc.
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CJ Spray, Inc.
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Clark & Pattison (BC) Ltd.
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Clemtex, Inc.
CMAX, LLC.
CMP Coatings, Inc.
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Coating Services, Inc.
Coating Systems, Inc.
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Coatings Unlimited Inc. (WA)
Coatings Unlimited, Inc.
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Cold Jet LLC
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Colonial Surface Solutions, Inc.
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Colorado Lining International
Commercial Sand Blasting & Painting
Commercial Sandblast Company
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Concare Inc.
Consulex
Copia Specialty Contractor, Inc.
Corcon Inc.
Corporacion MARA S.A.
Corporación Peruana de Productos Químicos SA.
Corrosion Prevention Technologies
Cosmos Industrial Services Inc.
County Group Companies
Crescent Coatings & Services, Inc.
Crown Painting, Inc.
CRP Industrial
CSI Services, Inc.
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Cypress Bayou Industrial Painting, Inc.
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DACA Specialty Services
Dalian YuXiang
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Danos
Darran Green Sandblasting & Painting
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DeFelsko Corporation
Dehumidification Technologies, LP
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Demos Painting & Decorating, Inc.
Denso North America Inc.
Derochie Painting Ltd.
Derrick Company Inc.
DESCO Manufacturing Company, Inc.
Detroit Tarpaulin, Inc.
Devco Sandblasting & Industrial Coating, Inc.
Devox S.A.
Dewr Mitra Indonesia PT
Diamond Vogel Paint Company
Distribuidora Kroma S.A. de C.V.
Dixon Engineering, Inc.
DMA Floors
Dodd Coating, Consultant & Inspection Service Inc.
Doosan Portable Power
DRS Environmental Systems
DRYCO, LLC
Drynamic Equipment
Drytec Trans Canada
Dubai Coating Limited
Dumond Chemicals
Dun-Right Services
Dunlap Industrial Coatings
Dur-A-Flex, Inc.
Dura-Bond Pipe, LLC
E. Caligari & Son, Inc.
E.J. Chris Contracting Inc.
Eagle Industrial Painting LLC.
Eagle Painting & Maintenance Co.
Eagle Specialty Coatings
EASE Painting and Construction
East Coast Repair & Fabrication
Eco CorFlex
Ecoblasting
EDCO-Equipment Development Co., Inc.
Elcometer
Elektro-Physik USA, Inc.
Elite Contractors, Inc.
Elite Industrial Painting, Inc.
EMI International LLC
EnDiSys
Endura Manufacturing Company Ltd.
EnTech Industries, LLC
Environmental Coating Services LLC
Environmental Planning & Management, Inc.
Envirosafe Stripping Inc.
EPAcoat, Inc.
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Era Valdivia Contractors, Inc.
Erie Painting and Maintenance, Inc.
Ervin Industries, Inc.
Euro Paint LLC.
Euro Style Management, Inc.
Excel Engineering & Contracting Co.
Extreme Coatings, Inc.
F.T.I. District Council 57 J.A.T.F.
Farr Construction Corporation
Farwest Corrosion Control Company
FASI Coatings
FCS Group LLC
Fedco Paints And Contracts
Fine Painting And Allied Services, LLC.
Finishing Plus
Finishing Systems of Florida, Inc.
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FTI of DC77
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Grace Distributing Inc.
Gracie Painting LLC
Graco Inc.
Green Diamond Sand Products
Greener Blast Technologies
Groome Industrial Service Group
Growell Blastec Co., Ltd.
GS Engineering & Construction Corp.
Gulf Coast Contracting, LLC
Gunderson, Inc.
Guzzler Manufacturing, Inc.
H D Water Jetting
H.I.S. Painting, Inc.
Hall Industrial Contracting, Ltd.
Hancock Sandblast & Paint LLC
Hanson Pressure Pipe
Harrison Muir, Inc.
Hartman-Walsh Painting Company
HCI Chemtec Inc.
HCI Industrial & Marine Coatings Inc.
HDR-Schiff Associates
Hempel China Ltd.
Henkels & McCoy
Hercules Painting Company
High Steel Structures, Inc.
Highland International, Inc.
HippWrap Containment
Hire Painting Inc.
HoldTight Solutions Inc.
Honolulu Painting Company, Ltd.
Howell & Howell Contractors, Inc.
HRV Conformance Verification Associates, Inc.
Hulsey Contracting Inc.
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Huntsman Polyurethanes
Hurricane Construction, Ltd.
HVEA Engineers
Hydraulics International Inc.
Hyundai Engineering & Steel Industries Co Ltd.
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IDS Blast Finishing
IMETECO S.A.
Impresa Donelli, S.R.L.
In-Spec Corporation Pte. Ltd.
Indian Valley Industries, Inc.
Induron Coatings, Inc.
Industrial Corrosion Control, Inc.
Industrial Marine, Inc.
Industrial Painting Limited, Inc.
Industrial Painting Specialists
Industrial Specialists LLC
Industrial Technical Coatings, Inc.
Industrial Vacuum Equipment Corp.
Insulating Coatings Corporation
Intech Contracting LLC.
Inter-City Contracting, Inc.
International Flooring & Protective Coatings, Inc.
International Rigging Group, LLC.
Interpaints SAC
Intertek Industry Services
Ionion Painting
IPAC Services Corporation
Iron Bridge Constructors, Inc.
IS2 / V2 Composites
ISTI Plant Services
IUPAT, District Council #5
J. Goodison Company, Inc.
J. Mori Painting Inc
JAD Equipment Co. Inc.
Jag'd Construction, Inc.
Jal Engineers Pvt. Ltd.
Jamac Painting & Sandblasting Ltd.
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K.V.K. Contracting Inc.
Kane, Inc.
Keene Coatings Corp.
Kennametal Inc.
Kern Steel Fabrication, Inc.
Kiewit Corporation
Kiewit Offshore Services, Ltd.
Kimery Painting, Inc.
Kiska Construction, Inc. (KCI)
Klicos Painting Company, Inc.
KMX Painting, Inc.
Knowles Industrial Service Corporation
Kopak Industries
L & L Painting Company Inc.
L Z Painting Co.
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Larson Electronics, LLC.
Ledcor Coating & Insulation Ltd.
Leighton Associates, Inc.
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Liberty Maintenance, Inc.
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Natrium Products, Inc.
Negocios Metalurgicos SAC
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New Kent Coatings Inc.
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NexTec Inc.
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Novatek Corporation
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Nu Way Industrial Waste Management LLC
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O.T. Neighoff & Sons, Inc.
Odle, Inc.
Olimag Sand, Inc.
OLS Restoration, Inc.
Olympus & Associates, Inc.
Olympus Painting Contractors, Inc.
Ontario Painting Contractors Association
OPT CO
Opta Minerals, Inc.
Optimiza Protective & Consulting, SL.
Orfanos Contractors, Inc.
Oxifree Metal Protection
P & L MetalCrafts LLC
P & S Painting Co., Inc.
P & W Painting Contractors Inc.
P S Bruckel Inc.
P&P Contracting, Inc.
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Pacific Coast Contracting Services, Inc.
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Pacific High Technology Engineering Services
Pacific Painting Co Inc.
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Park Derochie, Inc.
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Pro-Spec Painting, Inc.
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Professional Application Services, Inc.
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PT. Safinah Laras Persada
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Quality Assured Industrial Coatings
Quality Linings & Painting, Inc.
Quantum Technical Services
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Quinn Consulting Services, Inc.
R & B Protective Coatings, Inc.
R & S Steel, LLC
Rainbow, Inc.
RAK Paints LLC
Rapid-Prep, LLC
Raven Lining Systems
Razorback, LLC
RBW Enterprises
RECAL RECUBRIMIENTOS, SA de CV
Recal, LLC
Redi-Strip Metal Cleaning Canada Ltd.
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Righter Group, Inc.
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Rizzo Brothers Painting Contractors Inc.
RML Construction
Rogers Industries, LLC
Rotha Contracting Company, Inc.
Rover Contracting Inc.
Royal Bridge Inc.
S & D Industrial Painting Inc.
S & S Bridge Painting, Inc.
S & S Coatings, Inc.
S. David & Company, Inc.
Sabelhaus West, Inc.
SAFE Systems, Inc.
Safespan Platform Systems, Inc.
Safety Lamp of Houston
Saffo Contractors, Inc.
Safway Gulf Coast
Sahara Sandblasting and Painting Ltd.
Samac Painting
Sand Express
Sauereisen
Scafom Canada
Scicon Worldwide BVBA
Seaway Painting LLC
Secondary Services, Inc.
See Hup Seng CP Pte. Ltd.
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Seminole Equipment, Inc.
Service Contracting, Inc.
Services Acquisition Co LLC dba Tank Services
Servicios Tecnicos Industriales y Maritimos, S.A. (SETIMSA)
Seymour Midwest
Shanghai Genesis Chemmical Industry Co. Ltd.

Shanghai Yizhong Information Technology Co. Ltd.
Sherwin Williams Brasil
Sherwin-Williams Industrial & Marine Coating China
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Simpson Sandblasting and Special Coatings, Inc.
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Skyline Steel LLC
SME Steel Contractors
SOEP PAINTING CORPORATION
Soil & Materials Engineers, Inc.
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Sonic Coating Solutions Inc.
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Southern Painting & Blasting, LLC
Southern Road & Bridge, LLC
Southland Painting Corporation
Spartan Contracting, LLC
Specialty Application Services, Inc.
Specialty Finishes, LLC
Specialty Groups, Inc.
Specialty Polymer Coatings, Inc.
Specialty Products, Inc.
Spensieri Diversified LLC
Spider
Spiegel Industrial
Sponge-Jet, Inc.
Sprayroq Inc.
SRI Construction LLC
SRT Sales and Service, LLC
Stantec
Steel Fabricators of Monroe, LLC
Steel Management Systems, LLC
Steel Painters Inc.
Steele Consulting Inc.
Stinger Bridge & Iron
Stork Technical Services
Straight Line Industrial Services
Structural Coatings, Inc.
Sulzer Mixpac USA, Inc.
Sunbelt Rentals
Superior Industrial Maintenance Co.
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Surface Prep Supply
Surface Preparation & Coatings, LLC.
Swalling Construction Company, Inc.
Swanson & Youngdale, Inc.
Symmetric Painting, LLC
T & W Industrial Services LLC.
T Bailey, Inc.
T-Tex Equipment L.P.
Tamimi Company Commercial Division
Tarps Manufacturing, Inc.
TDJ Group, Inc.
Team Industries, Inc.
Techno Coatings, Inc.
Tecnico Corporation
Temp-Coat Brand Products, LLC
TERRY McGILL INC.
Tesla NanoCoatings, Inc.
Testex, Inc.
Tetra Tech
Texas Bridge, Inc.
The Aulson Company, Inc.
The Aulson Company, LLC
The Blastman Coatings Ltd.
The Corrosion Institute of the Caribbean
The Gateway Company
The Nacher Corporation
The Rodriguez Corporation
The Rose Corporation
The University of Akron
The Valspar Corporation
The Warehouse Rentals and Supplies
Thomarios
Thomas Industrial Coatings, Inc.
Thompson Metal Fab, Inc.
TIB Chemicals AG
Tidal Corrosion Services LLC.
Tidewater Staffing, Inc.
Timco Blasting & Coatings, Inc.
Tioga Air Heaters, LLC.
Titan Industrial Services
Titan Tool
TJC Painting Contractors, Inc.
TMI Coatings, Inc.
TMS Metalizing Systems, Ltd.
Tony Painting
Topline Limited
Tower Inspection Inc.
Tower Maintenance Corp.
TQC B.V.
Tractel Inc. Griphoist Division
Trailboss Enterprises, Inc.
Trask-Decrow Machinery
Travis Industries, LLC
Tri-Krete Coatings Inc.
Tri-State Painting, LLC
Trinity Industries de Mexico S. de R. L. de C.V.
Triple S&P, Inc. dba Dixie-Southern
TRUQC LLC.
Turman Commercial Painters
Turner Coatings LLC
Turner Industries Group, LLC
U.S. Tank Painting, Inc.
UHP Projects, Inc.
Uni-ram Corporation
United Decorating Inc.
Universal Acoustic & Emission Technologies, Inc.
US Coatings, Inc.
US Minerals/Stan Blast
Utility Service Company, Inc.
V. V. Mineral
Van Air Systems
Vanwin Coatings of VA, LLC
VeMac Inc.
Venus Painting Co.
Vermillion Painting & Construction
VersaFlex Incorporated
Versatile Painting & Sandblasting
Ville Platte Iron Works, Inc.
Vimas Painting Co., Inc.
Vision Painting & Decorating Services
Vision Point Systems
Vitro Minerals
Vulcan Painters, Inc.
W Abrasives
W Q Watters Company
W S Bunch Company
W W Enroughty & Son, Inc.
Wartsila Defense, Inc.
Wasser High-Tech Coatings, Inc.
Waveland Services Inc.
Wenrich Painting, Inc.
Western Industrial Services, Ltd.
Western Industrial, Inc.
Western Technology, Inc.
Wheelabrator
Wheelblast, Inc.
Wilkinson Sandblasting, LLC
WIWA LP
Worldwide Industries, Inc.
Worth Contracting
Xi'an Jing-Jian Paint & Coatings Group
Xinjiang Hongshan Coatings Co., Ltd.
XO Science LLC
Yankee Fiber Control, Inc.
Yellow Creek Coating Services
YYK Enterprises, Inc.
Zachry Industrial, Inc.
Zebron Corporation
Ziegler Industries Inc.
Zingametall BVBA
ZRC Worldwide

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American Coatings Association
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CDPH, Child Lead Poisoning Prevention Branch
PRA Coatings Technology Centre

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Air Products & Chemicals, Inc.
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Atsalis Brothers Painting Co.
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Avalotis Corporation
Brand Energy Solutions
Brock Services, LLC
C.A. Hull
Cannon Sline Industrial
Certified Coatings Company
Champion Painting Specialty Services Corp.
Clemco Industries Corp.
Cloverdale Paint, Inc.
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Cornerstone Painting Contractors, Inc
Corrosion Resistance
Dalco Services, Inc.
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Dex-O-Tex division Crossfield Products Corp.
Dow Chemical Company
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Eagle Industries
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Fletch's Sandblasting & Painting, Inc.
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Graydaze Contracting Inc.
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Industrial Coatings Contractors, Inc.
Industrial Steel Construction Inc.
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ITPTS Technical Institute of Preparation and Surface Treatment
Jotun Paints, Inc.
Kelly-Moore Paint Company, Inc.
King Industries, Inc.
Kinyon Construction, Inc.
Kolona Painting & General Construction, Inc.
Landmark Structures
Long Painting Company
Magnum Energy Services Ltd.
Main Industries Inc.
MARCO
Martin Specialty Coatings, Inc.
Mid-Atlantic Coatings, Inc.
Mobley Industrial Services, Inc.
Mohawk Northeast, Inc.
Naval Coating, Inc.
Newage Painting Corp.
North American Coatings CL Coatings Division
North Star Painting Co., Inc.
Northwest Sandblasting & Painting, Inc.
NTS Inc.
Odyssey Contracting Corporation
Olympic Enterprises Inc.
Ostrom Painting & Sandblasting, Inc.
Polygon
Precon Marine Inc.
Pro Blast Technology Inc.
Pro Tank - Professional Tank Cleaning & Sandblasting
Puget Sound Coatings Inc.
Quality Coatings of Virginia, Inc.
Redwood Painting Company, Inc.
Rust-Oleum Corporation
San Diego Protective Coatings Inc.
Scott Derr Painting Co. LLC
Shinko Company Ltd.
Shopwerks Inc.
Sil Industrial Minerals, Inc.
SK Commercial Construction, Inc.
South Bay Sand Blasting & Tank Cleaning
Stebbins Engineering & Mfg. Co.
StonCor Group Canada Carboline/ Plasite Coatings Group
Sturgeon Services International
Surface Technologies Corporation
T. F. Warren Group
Tank Industry Consultants, Inc.
Termarust Technologies
TSC Training Academy
Williams Specialty Services, LLC

Index to Advertisers

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SSPC COURSES

Course information available at sspc.org

Dec. 3–4	C10 Floor Ctg Basics, Pittsburgh, Pa.
Dec. 5–6	C12 Spray App, Norfolk, Va.
Dec. 7–8	Conc Ctg Basics (CCB), Lakewood, Wash.
Dec. 7–12	Prot Ctg Insp (PCI) Levels 1 & 2, Rahway, N.J.
Dec. 7–12	BCI Levels 1 & 2, Newington, N.H.
Dec. 7–12	Conc Ctg Insp (CCI) Levels 1 & 2, Lakewood, Wash.
Dec. 7–18	PCI Levels 1 & 2, Singapore City, Singapore
Dec. 13	CCI Supplement, Lakewood, Wash.
Dec. 13	PCI Level 3, Rahway, N.J.
Dec. 19	PCI Level 3, Singapore City, Singapore

CONFERENCES AND MEETINGS

Dec. 1–3	International WorkBoat Show, New Orleans, La. workboatshow.com
Dec. 7–9	Construction SuperConference, San Diego, Calif. constructionsuperconference.com